FINAL REPORT

VOLUME 4

CONTINGENCY PROCESSING ANALYSIS

LAUNCH SITE PROCESSING OF HAZARDOUS PAYLOADS

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FOREWORD

This document constitutes Volume 4 of a seven-volume Final Report, prepared by Teledyne Brown Engineering, Huntsville, Alabama, under NASA Contract No. NAS10-8676, Launch Site Processing of Hazardous Payloads. This study required a thorough analysis of the impact on the launch site and its operations by hazardous Space Shuttle payloads.

The seven volumes of the Final Report are as follows:

Volume 1. EXECUTIVE SUMMARY: This volume presents a concise review of the results of the study tasks and summarizes the principal conclusions and recommendations of the study.

Volume 2. HAZARDOUS PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and analysis of proposed Shuttle payloads to identify hazardous payloads and define the characteristics of materials and systems which make them hazardous. This task included the development of a hazardous payloads ranking technique and recommendations for processing analysis on selected payloads.

Volume 3. NORMAL PROCESSING ANALYSIS: This volume presents preliminary normal processing flow plans for three Shuttle cargoes selected as a result of the Hazardous Payloads Survey and Analysis Task. These three cargoes are:

- Spacelab with Advanced Technology Laboratory
- Tug, Solar Electric Propulsion Stage, and Synchronous Earth Observatory Satellite
- Interim Upper Stage and a Pioneer Jupiter Probe with a Fluorine Propulsion Unit

The preliminary processing flow plans include identification of unique facilities and GSE, processing hazards, and payload safety related design criteria.

Volume 4. CONTINGENCY PROCESSING ANALYSIS: This volume presents preliminary alternate processing flow plans for contingency situations for the three Shuttle cargoes analyzed in the Normal Processing Analysis Task.

Volume 5. CURRENT PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and analysis to determine payloads that are currently flying and that may also fly on the Shuttle vehicle when it becomes operational. The analysis determines hazardous materials/systems for each of these current payloads and recommends design and operational safety criteria for each hazardous current payload to minimize its impact on the Shuttle Transportation System.

Volume 6. ENVIRONMENTAL IMPACT STATEMENT POTENTIAL REQUIREMENTS: This volume presents the results of an evaluation of the probable environmental impact of Shuttle payloads hazardous materials and includes recommended KSC Environmental Impact Statement Potential Requirements.

Volume 7. ADVANCED TECHNOLOGY REQUIREMENTS: This volume presents a list of special problems identified in the study which require advanced technology study or technology development.

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1.0 INTRODUCTION

Payloads containing hazardous materials associated with space vehicle launch operations have been recognized and dealt with on previous R&D space programs. However, when compared to the Shuttle Program, these R&D space programs involved relatively few launches with considerable time between launches. The Shuttle operational program will have a high launch rate and in many cases individual launches will have several independent payloads for accomplishment of separate missions. Some of these payloads by intent will be recoverable for purpose of reuse, and all must be recoverable in the sense that possible abort situations prior to deployment have to be recognized.

Present processing schedules have been derived assuming nominal passive payloads and nominal payload flow time. A number of specifically safety oriented studies on Shuttle payloads has been performed in recent years. However, relatively few of these have treated ground operations in depth, and the overall impact of Shuttle payload hazards on launch and landing site processing and procedures has not been documented. In order to fill this gap, this 10-month study was initiated in July 1974. The overall study objectives were to uncover and determine the hazard potential of Shuttle payloads, develop safety oriented normal and contingency launch site processing plans for selected cargoes that will minimize the impact on cost and schedules, and provide for environmental protection.

1.1 TASK OBJECTIVES

The objective of contingency analysis is to derive a set of alternative plans for emergency situations that can arise during the processing of hazardous payloads.

1.2 SCOPE

Since a contingency is any deviation in the set of conditions from which the normal base line processing was planned, there are many types of contingency situations ranging from schedule problems, failures or malfunctions and human errors, to accidents occurring during the processing operations. All of these types of contingencies need alternative plans if a return to normal or near normal operation is to be obtained or if a safe and effective backout with minimum damage to facilities and equipment, minimum injury, and minimum loss of time are to be expected.

In this study, the approach has been to analyze two categories of contingencies that involve cargoes:

- Contingencies not directly related to payload/cargo but occur while the cargo is Orbiter constrained.

- Contingencies directly related to payload/cargo and initiated by the occurrence of payload /cargo processing accidents.

In the first category,the concentration has been on the analysis of certain contingency situations that have wide and diverse applications and cover, in a general sense, most of the Orbiter constrained contingency conditions. Table I lists six types of contingencies (i.e., from the first category) versus the three cargoes.

TABLE I. CONTINGENCIES VERSUS CARGOES

TYPE OF CONTINGENCY	CARGO		
	SPACELAB/ATL	TUG/SEPS/SEOS	IUS/F_2PU/PJP
1. BACKOUT OPERATIONS	●	●	●
2. VERTICAL CHANGEOUT AT THE PAD	●	●	●
3. MISSION ABORT	●	●	●
4. NORMAL LANDING AT CONTINGENCY SITE	●	●	
5. CRASH / SHOCK CONDITION LANDING AT KSC	●	●	
6. CRASH / SHOCK CONDITION LANDING AT ALTERNATE SITE	●	●	

In addition to developing the 15 contingency plans shown above, one accident-type contingency, loss of Radioisotope Thermoelectric Generator (RTG) cooling was selected from the list of accident candidates, and a plan for loss of RTG cooling was developed.

For each of the 16 contingencies analyzed in this study, the following is being provided:

- An alternative flow plan for proceeding with near normal operations or for backing out with minimum loss.
- A waterfall/time line chart of the alternative flow for estimating schedule impact.
- A summary of special safing requirements.
- An identification of special support equipment.

1.3 TASK APPROACH

The approach for developing the contingency package is:

- Define the Objective, e.g., safe the cargo, backout from online operations, and demate as rapidly as possible.
- Identify safest and least time consuming operational sequence (an iterative process).

  --Define a workable operational flow to satisfy the objective.

  --Remove hazardous operations or, where possible, change the sequence to a less hazardous flow.

  --Identify parallel activities.
- Identify special support equipment requirements, facility protection, and personnel safety requirements.

1.4 SUMMARY OF RESULTS AND RECOMMENDATIONS

Normal feasible processing plans for the cargoes consisting of Spacelab/ATL/IRTCM, Interim Upper Stage (IUS)/Fluorine Propulsion Unit (F_2PU)/Pioneer Jupiter Probe (PJP), Tug/Solar Electric Propulsion Stage (SEPS)/Synchronous Earth Observatory Satellite (SEOS) were optimized through a series of iterative tradeoffs. These final iterations formed the normal base line processing flow plans. They were analyzed for weaknesses and susceptibility to hazards. Areas revealed to be particularly vulnerable to catastrophic and critical accidents were flagged for further consideration as candidates for contingency planning. Also, an examination of the normal base line processing flow for the areas of highest accident potential because of heavy hazard concentrations or caused by other considerations, such as the cargoes' being Orbiter constrained, indicated the need for contingency planning for pad backout operations, vertical changeout options at the pad, and mission abort plans. The base line processing flow covered landing and refurbishment operations for the Spacelab/ATL/IRTCM and Tug/SEPS/SEOS. In this task, normal landing at a contingency site as well as crash/shock condition landings at both KSC and at a contingency site were studied. Thus, a set of six general types of contingency plans was developed for these two cargoes. For the IUS/F_2PU/PJP, contingency planning for landing operations was not studied. A total of 15 general contingency plans was developed.

From the list of candidate accident contingencies, one accident-type contingency (loss of RTG cooling for the PJP on the IUS/F_2PU/PJP cargo) was selected for analysis. In addition to providing the contingency plans in flow chart form, the operations were timelined and a waterfall chart was derived for determining schedule impact on the normal processing operations. From an analysis of each contingency plan, essential facility modifications and special support equipment required for the successful deployment of that plan have been compiled and described.

The primary findings, conclusions, and recommendations resulting from the contingency analysis are as follows:

- Fluorine

  --The consequences of a major fluorine leak at landing during mission abort of the IUS/F_2PU/PJP cargo make it desireable that F_2 be dumped in space.

  --Mission abort and in-flight dump require a special F_2 vent and dump line. The Orbiter oxidizer dump system could be used (other oxidizers are primarily LO_2 and N_2O_4). This requires that the Orbiter oxidizer overboard vent systems' design and materials be F_2 compatible.

--Purge tanks should be provided for F_2 tank purge and inerting following in-flight dumping during abort. This is to remove residuals before landing.

--For mission abort of IUS/F_2PU/PJP when F_2 is dumped in-flight, it is recommended that final inerting of F_2 system be conducted at the landing strip or an intermediate facility before return to the Orbiter Processing Facility (OPF). This requires a heated GN_2 supply, a portable F_2 vent line system, and a disposal unit.

--(Alternate) If F_2 is not vented in-flight when the mission is aborted and the system remains intact through landing, it is recommended that the fluorinated propulsion unit be removed at the OPF and transferred to the F_2 facility for unloading. This requires a portable LN_2 cooling supply at the landing strip.

--Fluorine unit should be removed intact during pad backout or vertical changeout contingency unless a failure has occurred in the fluorine system.

--Payload Changeout Room (PCR) should have provisions for bringing LN_2 supply dewar to F_2PU level.

--Fluorine drain and disposal unit is required at the pad.

- Mercury

--Because of the consequence to the Orbiter from a major mercury leak at landing (contamination), it is recommended that mercury propellant be dumped before return in a mission abort situation.

--Mercury dump for abort could be through the Orbiter propellant vent system. The Mercury propellant vent line size should be studied.

--If mercury dumping is not performed for mission abort, the bladder must be pressurized during landing. The SEPS structure should be evaluated for 3000-lb shift of mercury.

--Mercury should not be removed from the SEPS for pad backout or vertical changeout contingencies.

--All Mercury transfer should be performed at the Mercury facility.

- Radiological (RTG's)

--RTG's will require a portable cooling unit at the landing strip for the mission abort contingency.

--Cooling system (onboard) should be designed for complete redundancy. It is suggested that the coolant shrouds have alternate coils supplied by separate systems.

--The RTG water cooling system integrity must be leak proof, i.e., considered the same as a hazardous fluid.

--The RTG water cooling should have relief valve and the cooling shroud and RTG unit should have a temperature monitor.

--Design of the RTG/Radioisotope Heater Unit (RHU) should be such that integrity of the units would be maintained in the event of a fire or explosion.

--Requires presence of trained and equipped radiological survey/decontamination teams.

2.0 CONTINGENCY SELECTION

Contingency selection is a logical process of analytically searching the normal base line processing flow for the most likely and catastrophic contingencies, examining possible alternative courses of action, and selecting the overall most desirable alternative from the candidates for implementation.

This process is illustrated in Figure 1. The first step in the contingency selection process is the identification of potential contingency situations. One of the main thrusts of this study has been the performance of a hazard analysis on the base line processing flow for the three cargoes. The hazard analysis has provided in-depth visibility for identifying potential contingency situations through recognition of hazardous operations, processes, materials, and systems. Since the hazard analysis covered the entire spectrum of ground processing operations and categorized hazards according to severity of impact, accident-type candidate contingency situations could be derived for various operations or events. In addition to using the hazard analysis as a vehicle for locating specific contingency situations, six general contingency situations in which wide spread interest has been shown were selected and developed. These contingencies shown in Paragraph 1.2 are not directly related to payload/cargo but occur while the cargo is Orbiter constrained.

Once a potential contingency has been identified (step one) and a need for an alternative flow has been decided upon, possible alternative courses of action must be examined (step two). For example, the contingency situation will be bumped against basic types of alternatives--workarounds, repair/replace and proceed, and changeout payload. For each feasible course of action, a rough estimate of its overall impact (step three) is made to assist in selecting the most desirable alternative (Step 4).

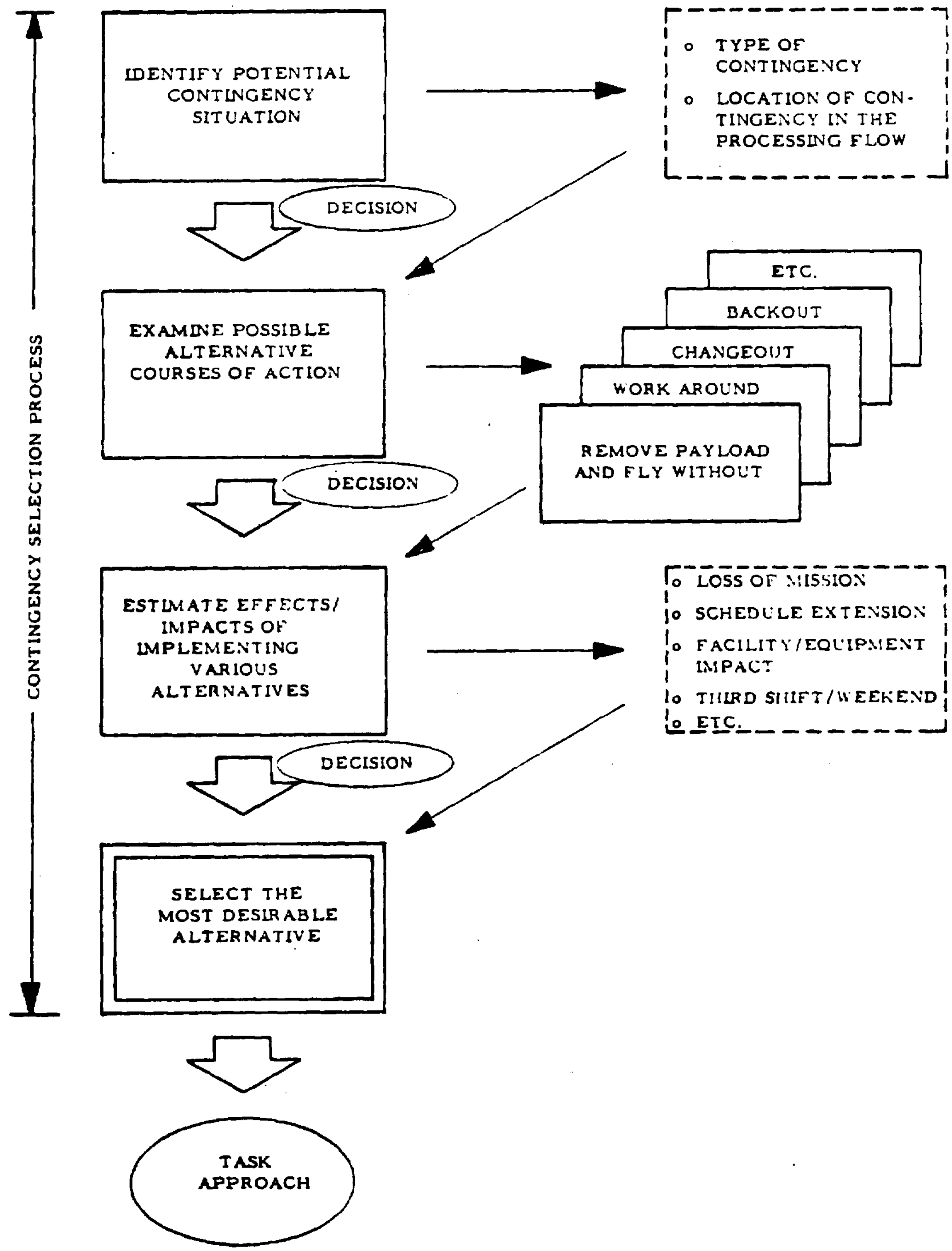

FIGURE 1. CONTINGENCY SELECTION PROCESS

The development of the normal processing base line flow was an iterative process of continually improving a workable processing plan until the best overall compromises in safety, schedule time, and facilities/equipment had been achieved. Through this feedback process, some hazardous operations were either eliminated, reduced, or replaced by less hazardous ones, or the sequence and/or locations changed so as to have a lesser impact. In essence, tradeoffs considering the above parameters of safety, time, and facilities were made in arriving at an intuitive optimum base line flow. This process is typified in Figure 2, which illustrates by a simple example the replacement of a section of the normal processing base line with an alternative method. The implication is that the analysis of the normal base line revealed a hazardous sequence of operations that can be replaced entirely by an alternative sequence that will then become an integral part of the optimum normal processing base line flow.

The detailed hazard analysis was performed on the optimum normal processing base line flow. The critical and catastrophic hazards uncovered as a result of this analysis were treated through recommendations designed to control them, or in lieu of appropriate or suitable recommendations an alternative flow for an accident-type contingency was proposed. This type of alternative is not to be mistaken for the previously discussed type of alternative that replaces another more hazardous sequence of operations in the iterative process of optimizing the normal base line processing flow. The alternative for a contingency situation is not an integral part of the normal base line processing flow but an alternative path to be used in the event that the undesired contingency occurs.

The alternative flows for contingencies of the three cargoes (i.e., Spacelab/ATL/IRTCM, Tug/SEPS/SEOS, and IUS/F_2PU/PJP) are discussed in Paragraphs 3.1, 3.2, and 3.3. A brief narrative description of each contingency alternative is presented with a discussion of the operational flows, time lines, and summary of safing requirements. Constraints and areas of major design impact are also noted. It should be emphasized that these contingency flows, time lines, and safing requirements have been developed for the purpose of providing the safest method of return to a normal or near-normal condition. Depending upon the initiator of a contingency situation, some of the desired safety precautions and constraints may have to be omitted if a catastrophic situation is imminent. This would require for each situation that a comparison be made of the relative risk from proceeding on a contingency plan in a less safe manner versus the risk of an imminent catastrophic condition.

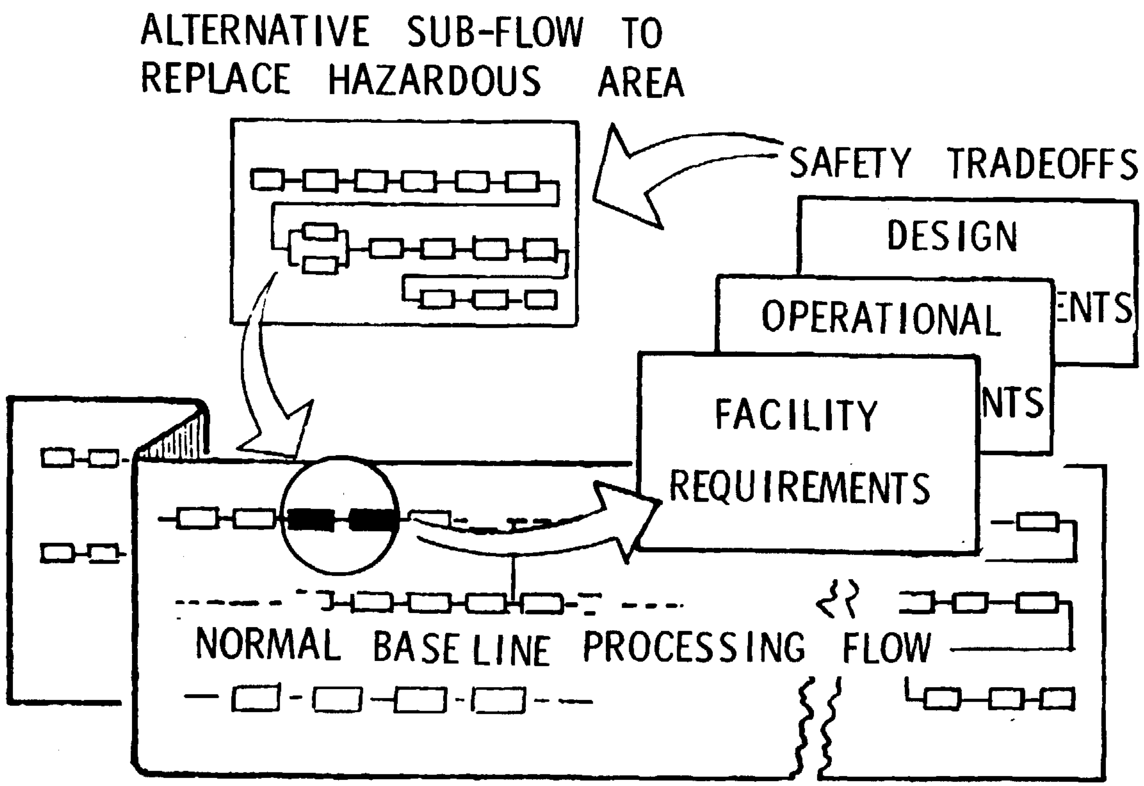

FIGURE 2. NORMAL BASE LINE FLOW TRADEOFFS

3.0 CONTINGENCY ANALYSIS

3.1 SPACELAB/ATL/IRTCM CARGO CONTINGENCY PLANS

3.1.1 Vertical Changeout at the Pad

This alternative is for those situations where the decision is to remove the Spacelab/ATL/IRTCM cargo at the pad and to replace it with another cargo. This is a general-type contingency situation and the specific cause or reason for the decision to change out is not defined. If the reason were because of an accident, a failure, etc., the specific reason would have to be addressed and the peculiarities of the cause would have to be treated. This alternative plan requires two canisters: one that contains the Spacelab/ATL/IRTCM cargo and one on standby that contains an optional cargo. The problem of having a payload changeout room capable of handling two cargoes simultaneously was not addressed in this alternative because it will be presented in the flows of the IUS/F_2PU/PJP cargo.

3.1.1.1 Time Line

The vertical changeout from initiation of the contingency to launch of the new cargo is approximately 75 hr. The operations required to remove the Spacelab and the sequence are shown on Figures 3 and 4. A nominal time line and sequence of operations for installation of another payload in the Orbiter are shown. Since there are no provisions for installation of a Spacelab cargo in the Orbiter in the vertical position, installation steps for the new cargo are at a level to be applicable to any payload.

3.1.1.2 Safing Requirements

Depending upon the point in the Shuttle countdown where the vertical changeout contingency operation is initiated, the safing requirements that must be completed to ensure safety of operations personnel and protection of facilities and the payload are as follows:

- The Shuttle must be deserviced and safed and the pad reopened.
- Spacelab GO_2/GN_2 pressure bottles should be vented to remove the high pressure hazard. The current ESRO

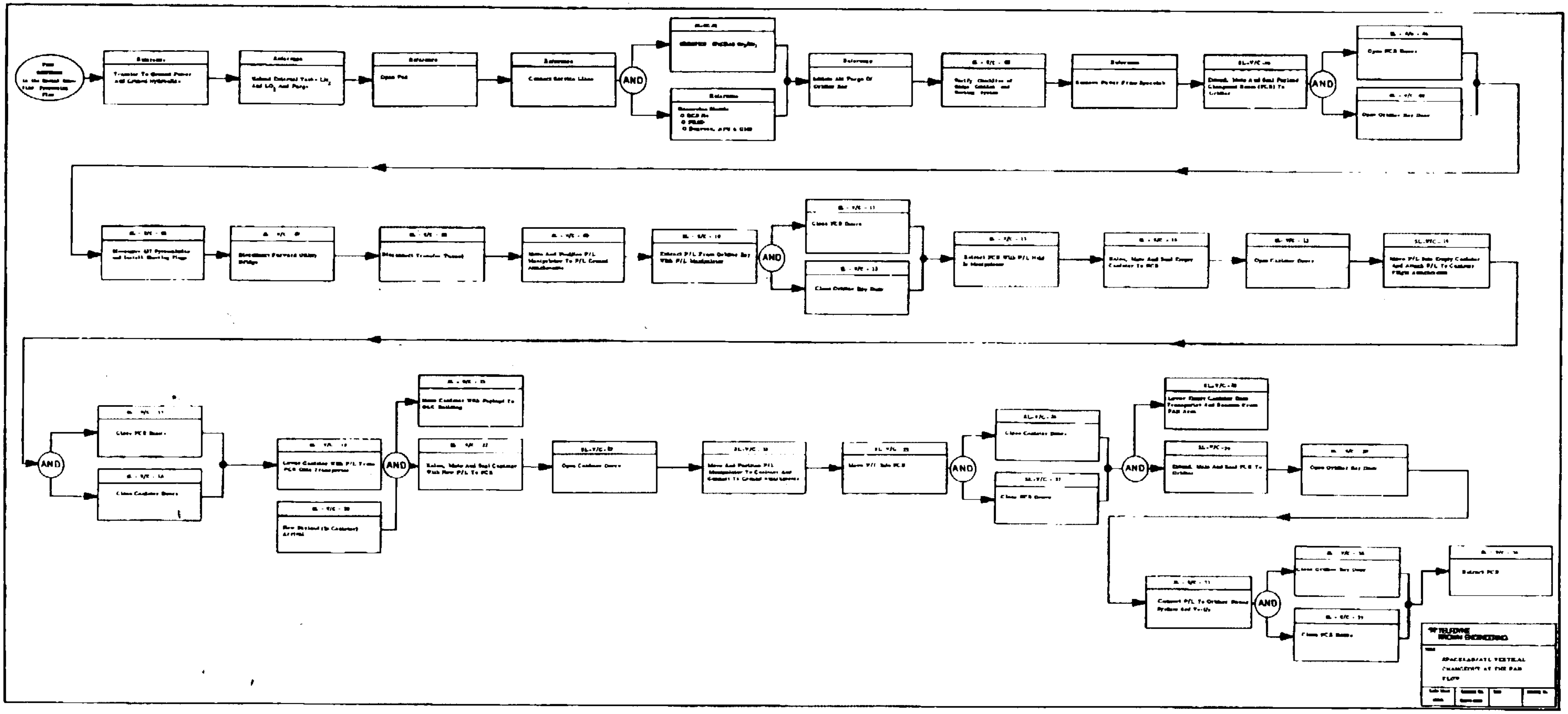

FIGURE 3. SPACELAB/ATL VERTICAL CHANGEOUT AT THE PAD FLOW

12 - A

12 - B

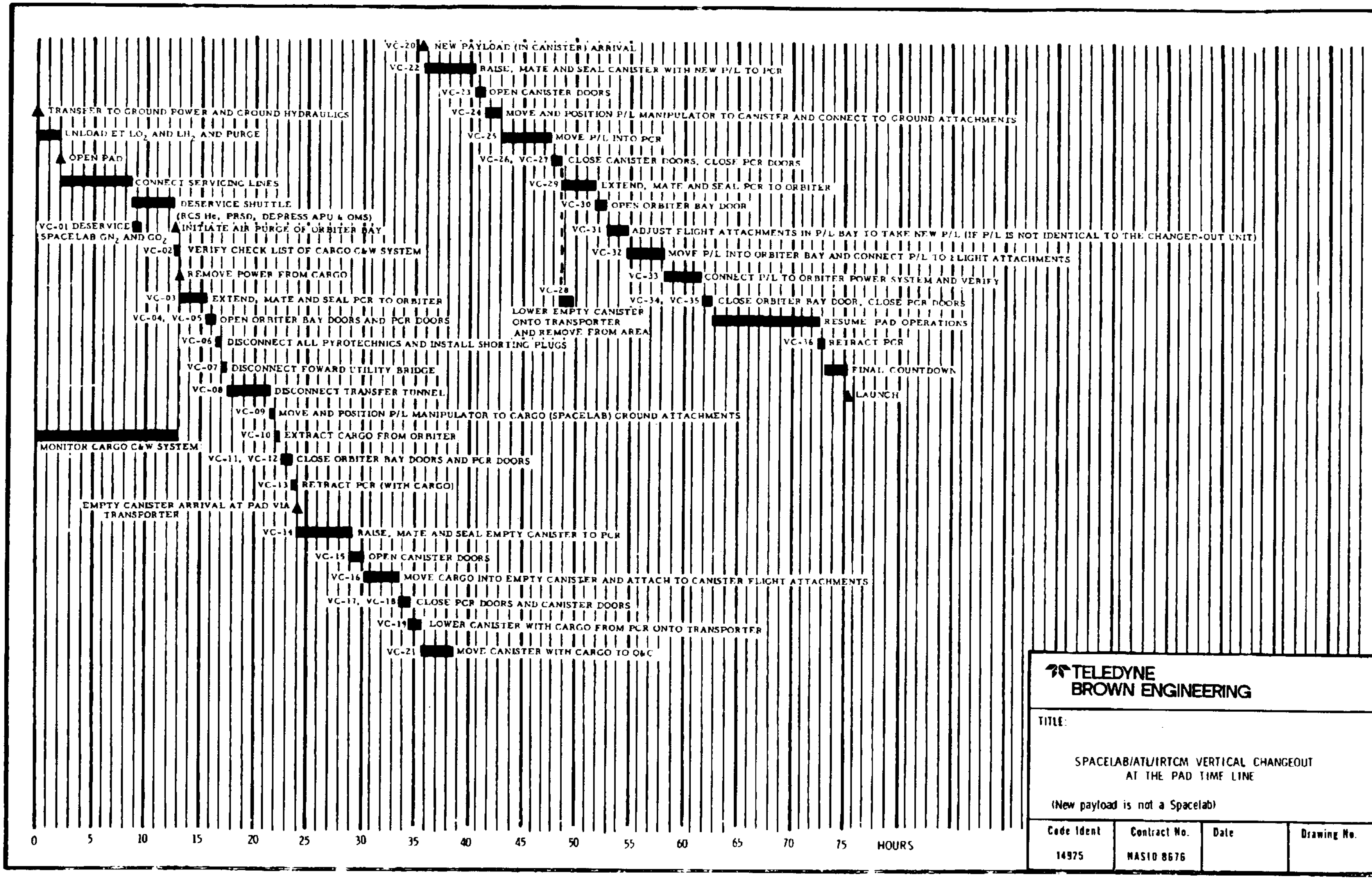

FIGURE 4. SPACELAB/ATL VERTICAL CHANGEOUT AT THE PAD TIME LINE

13-A

Spacelab design provides a nonpropulsive vent on the forward bulkhead of the Spacelab that dumps into the cargo bay. Venting of N_2 should present no special problems. However, venting of O_2 or O_2/N_2 together may increase chances of a fire hazard in the cargo bay. Either the O_2/N_2 vent line should be connected to the Orbiter vent system or O_2 venting must be accompanied by a high flow rate air or N_2 cargo bay purge.

- Disconnect all pyrotechnics and install shorting plugs. This safing requirement will have a significant impact on the Spacelab design and require access in the vertical position from the cargo bay if done at the pad. This would also require special access platforms/mechanisms such as is shown in paragraph 3.5, Item C-1.

- An alternate to pyrotechnics safing at the pad would be to perform this function upon arrival at the OPF as is done in the normal post flight operational sequence. This approach exposes the operational personnel to a hazard from inadvertent actuation of the boom jettison systems since access will be required to manually disconnect the utility bridge and disconnect the tunnel. If this approach is required because of access limitations, mechanical safe and arm devices should be included in the design of all pyrotechnics or mechanical release devices should be used rather than pyrotechnics.

- Removal of the Spacelab requires separation of the Freon Thermal Control System (TCS) loop that interconnects the Spacelab ECS system and the Orbiter radiator. Drain, flush, and purge of these lines are not considered necessary for safing prior to Spacelab removal but present a contamination problem. It is recommended that the Freon system be designed so that a disconnection when charged is possible with minimal leakage.

3.1.2 Backout Operations

The backout contingency like the changeout contingency is a general flow that is applicable to any Spacelab cargo. Because it is general, specific reasons (such as a particular type of accident being the initiating cause of the backout) are not addressed in this flow. The assumption is that the cause is controllable or has been arrested, thus presenting no special or unique fix at the pad.

3.1.2.1 Time Line

The backout operation from initiation of backout to arrival at the O&C Building with the removed payload is approximately 35 hr. The operations required to perform the Spacelab removal and their sequence are shown in Figures 5 and 6.

3.1.2.2 Safing Requirements

The safing requirements for this contingency are identical to the Spacelab vertical changeout operations given in paragraph 3.1.1.2.

3.1.3 Mission Abort

This contingency requires in-flight safing of the Orbiter and cargo. Our primary concern, however, is with the cargo. Since the abort can take place at various points within the mission, cargo related safing must be examined in light of the worst case assumption that various experiments could be in process and thus must be dealt with accordingly.

3.1.3.1 Time Line

The mission abort contingency flow is shown in Figure 7. The time required to safe the cargo for abort depends upon the operations in progress and time into the mission. Because of the number of possible combinations of operation,a time frame is impractical to determine.

3.1.3.2 Safing Requirements

The following safing operations must be performed for a mission abort and return to a normal landing.

- All booms and antennae that are deployed at the time of the abort decision must be retracted or jettisoned if unable to retract because of a mechanical malfunction or insufficient time. Included in this operation is safing of all unexpended ordnance.

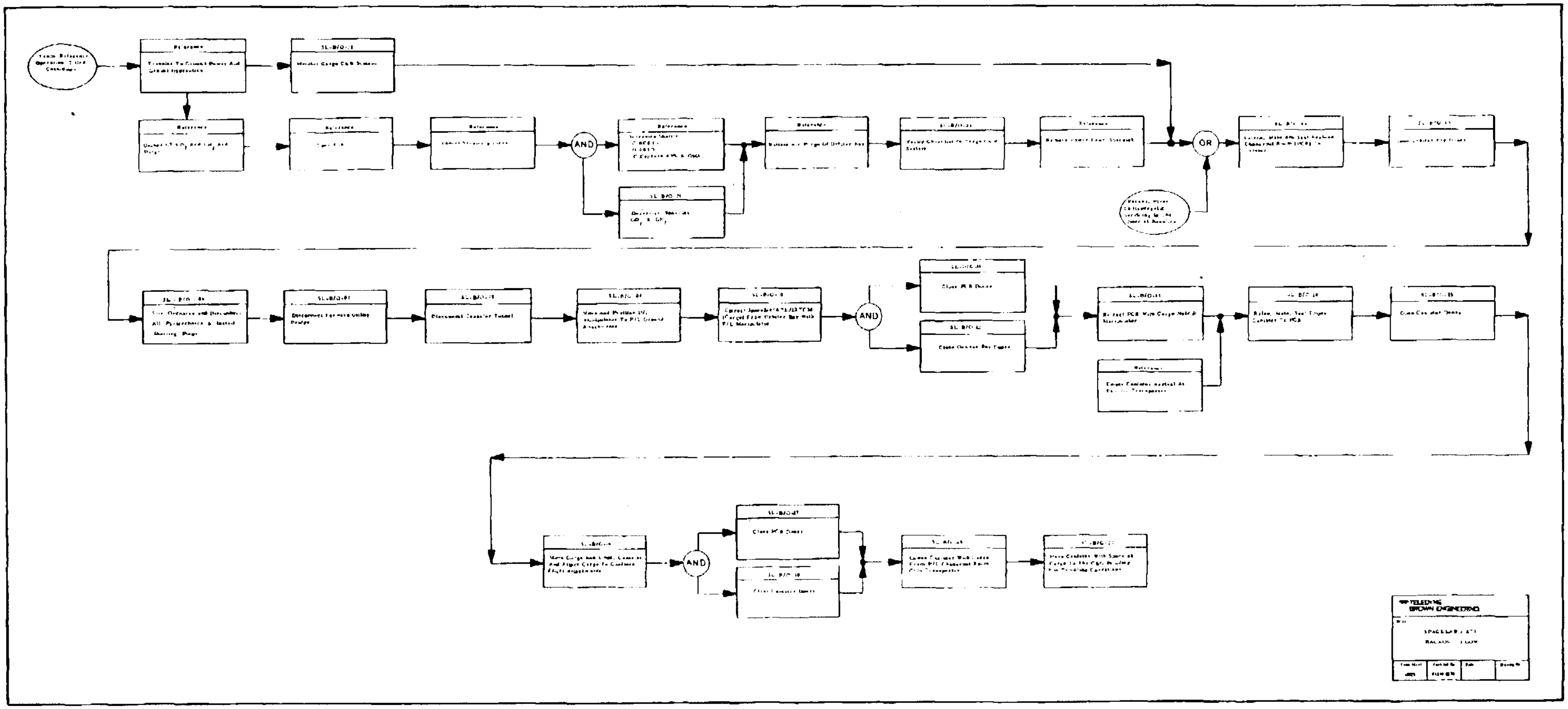

FIGURE 5. SPACELAB/ATL BACKOUT FLOW

16-A

16 -B

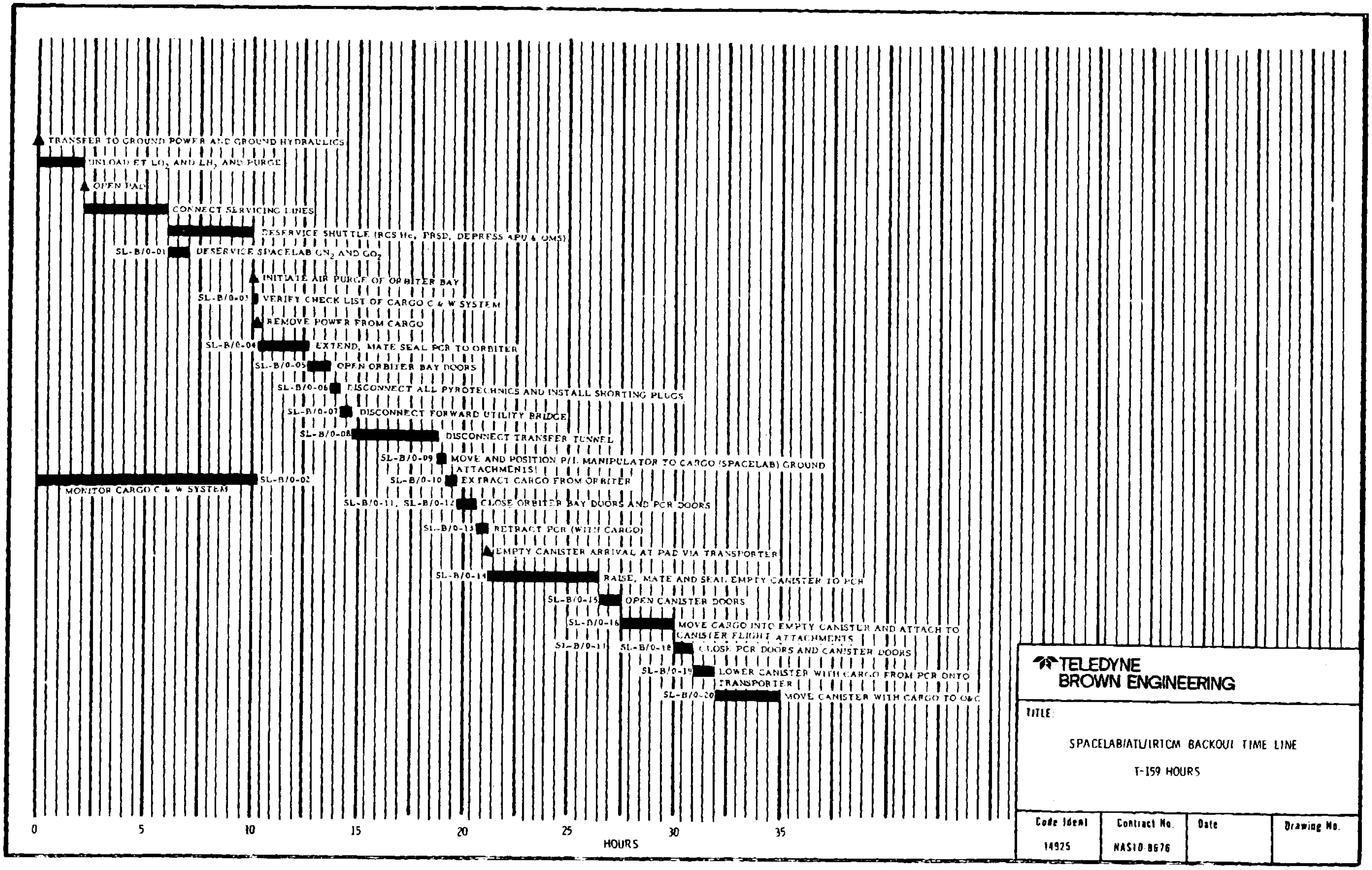

FIGURE 6. SPACELAB/ATL BACKOUT TIME LINE

17-A

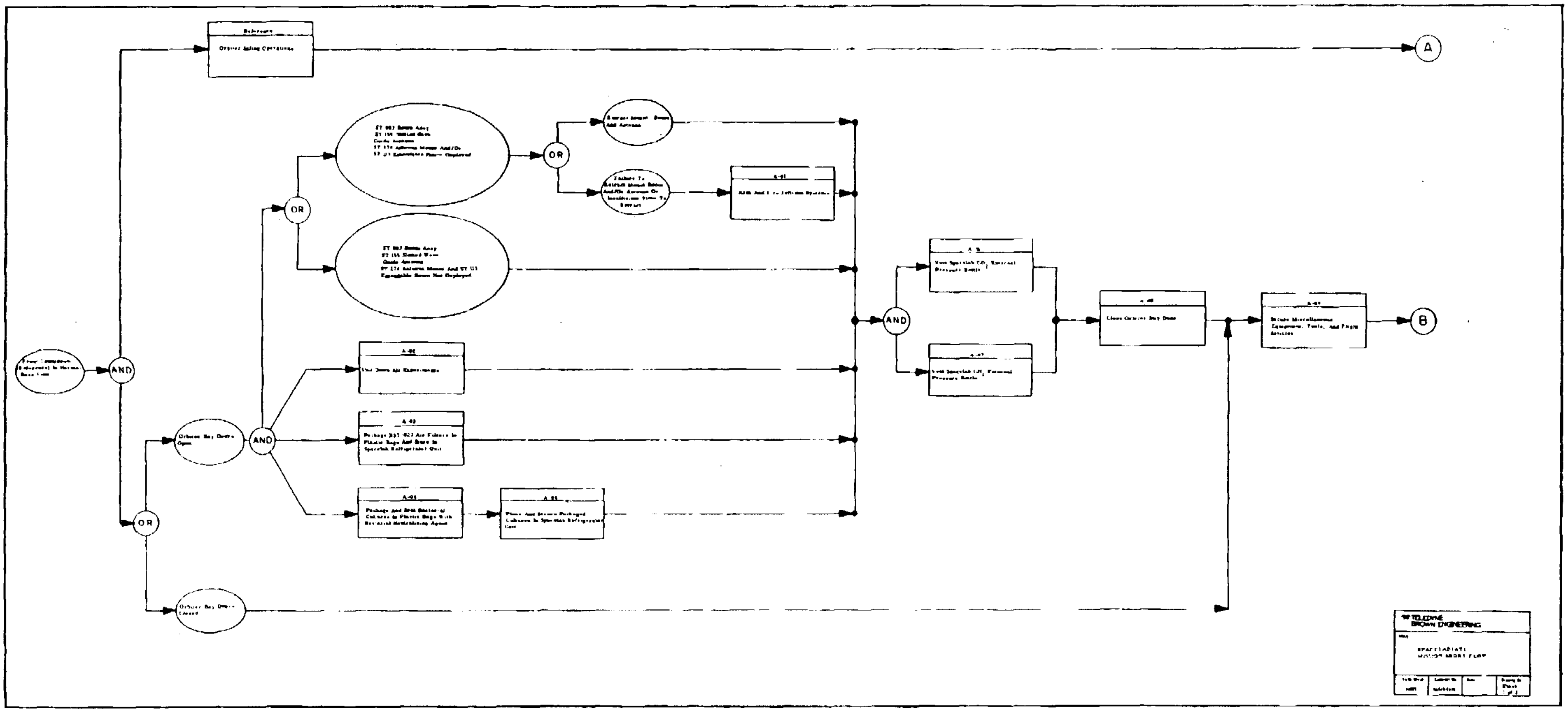

FIGURE 7. SPACELAB/ATL MISSION ABORT FLOW (SHEET 1 of 2)

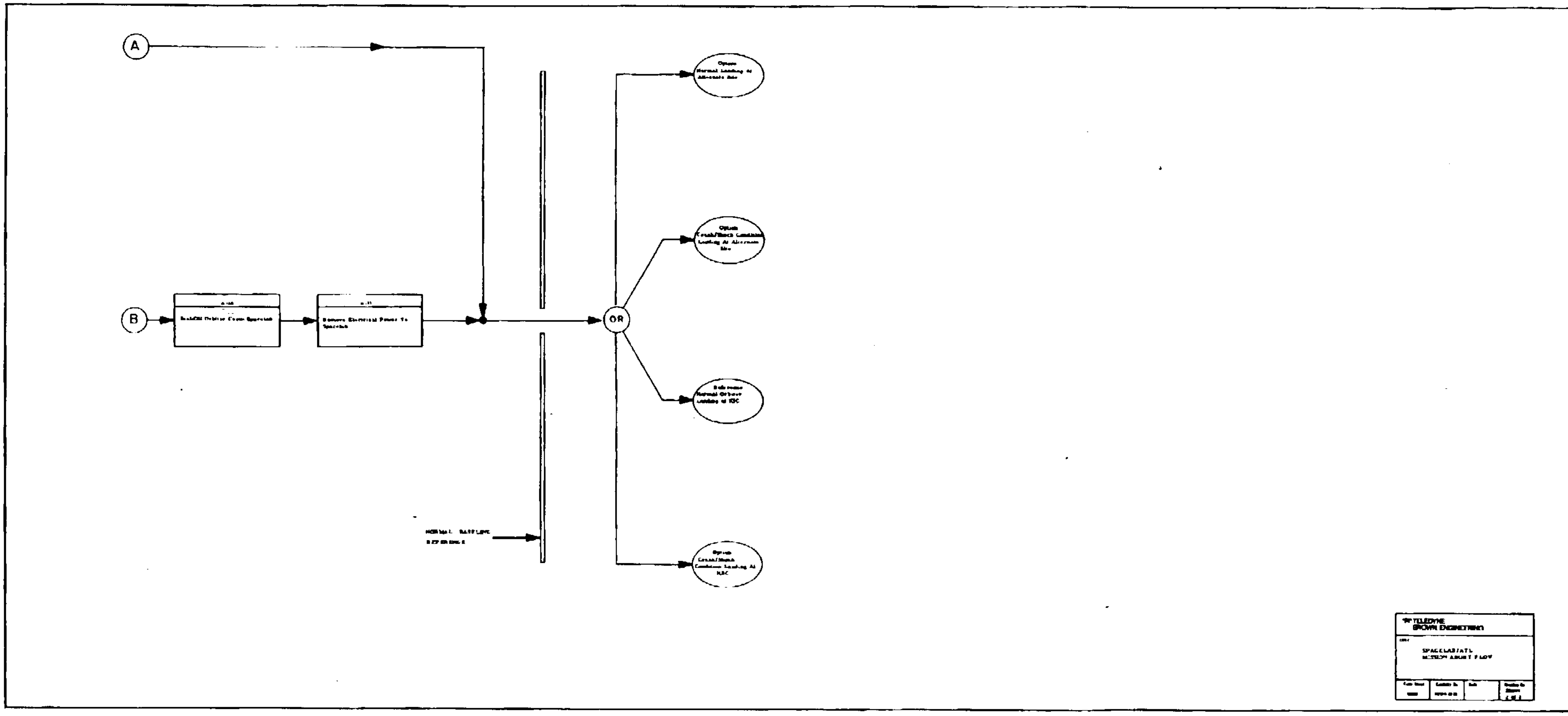

FIGURE 7. SPACELAB/ATL MISSION ABORT FLOW (SHEET 2 of 2)

19 A

- All other experiments must be shut down and safed and pressures vented.

- Bacterial cultures must be safed and secured.

- GO_2 and GN_2 pressure bottles must be vented. The ESRO Spacelab design currently provides a nonpropulsive vent on the forward bulkhead of the Spacelab for venting into the cargo bay. Since the first abort opportunity is at Solid Rocket Booster (SRB) burnout ($\sim$140,000 ft), O_2/N_2 vented into the cargo bay would be dispersed to space through the vent ports.

- Miscellaneous equipment, tools, and flight articles should be secured and the Orbiter sealed off from the Spacelab prior to power removal.

3.1.4 Normal Landing at a Contingency Site

This is a general-type contingency situation where the Spacelab cargo is Orbiter constrained, and to adequately handle the cargo, attention must be concentrated on the Orbiter requirements first. The decision to land at a contingency site may or may not be a result of a prior mission abort. The contingency flow developed for landing at a contingency site was for the worst case. It was assumed that the site was not prearranged for an Orbiter landing and had no special support equipment and no special trained maintenance personnel for the post-landing tasks. It was further assumed that as much Orbiter safing as possible will be performed with the types of equipment that can be brought to the contingency site. Another assumption made to establish this contingency was that a special equipped carrier plane such as a Boeing 747 would bring the required support equipment to the site and also return with it and the Orbiter to KSC. It was also assumed that the Spacelab film, recorded data, and microbiological cultures could be removed at the contingency site if it were considered imperative.

3.1.4.1 Time Line

The normal landing at a contingency site flow is shown in Figure 8. The time required to safe and prepare the Orbiter and payload for transport to KSC depends upon the distance and time of arrival of personnel and equipment. The time line for this contingency is shown in Figure 9.

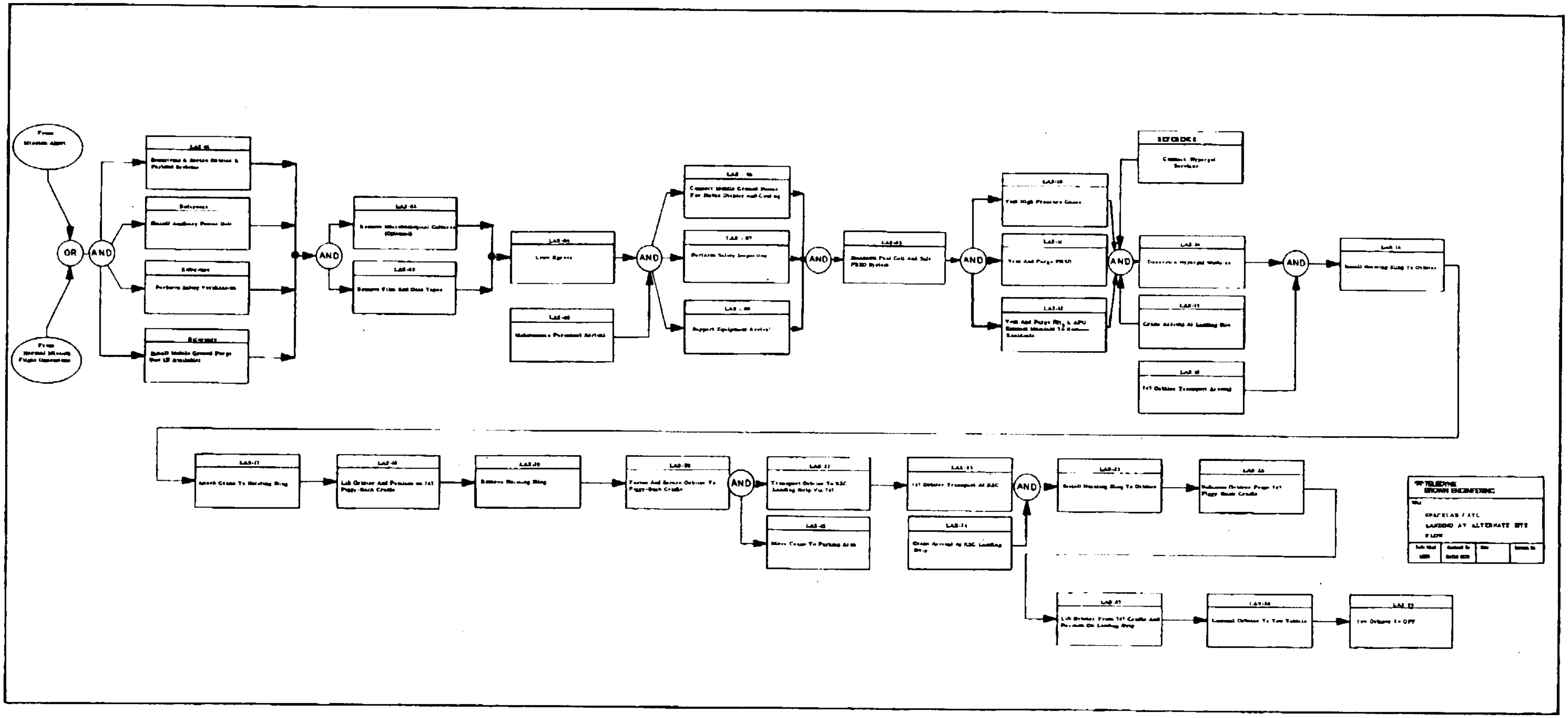

FIGURE 8. SPACELAB/ATL LANDING AT ALTERNATE SITE FLOW

2/ A

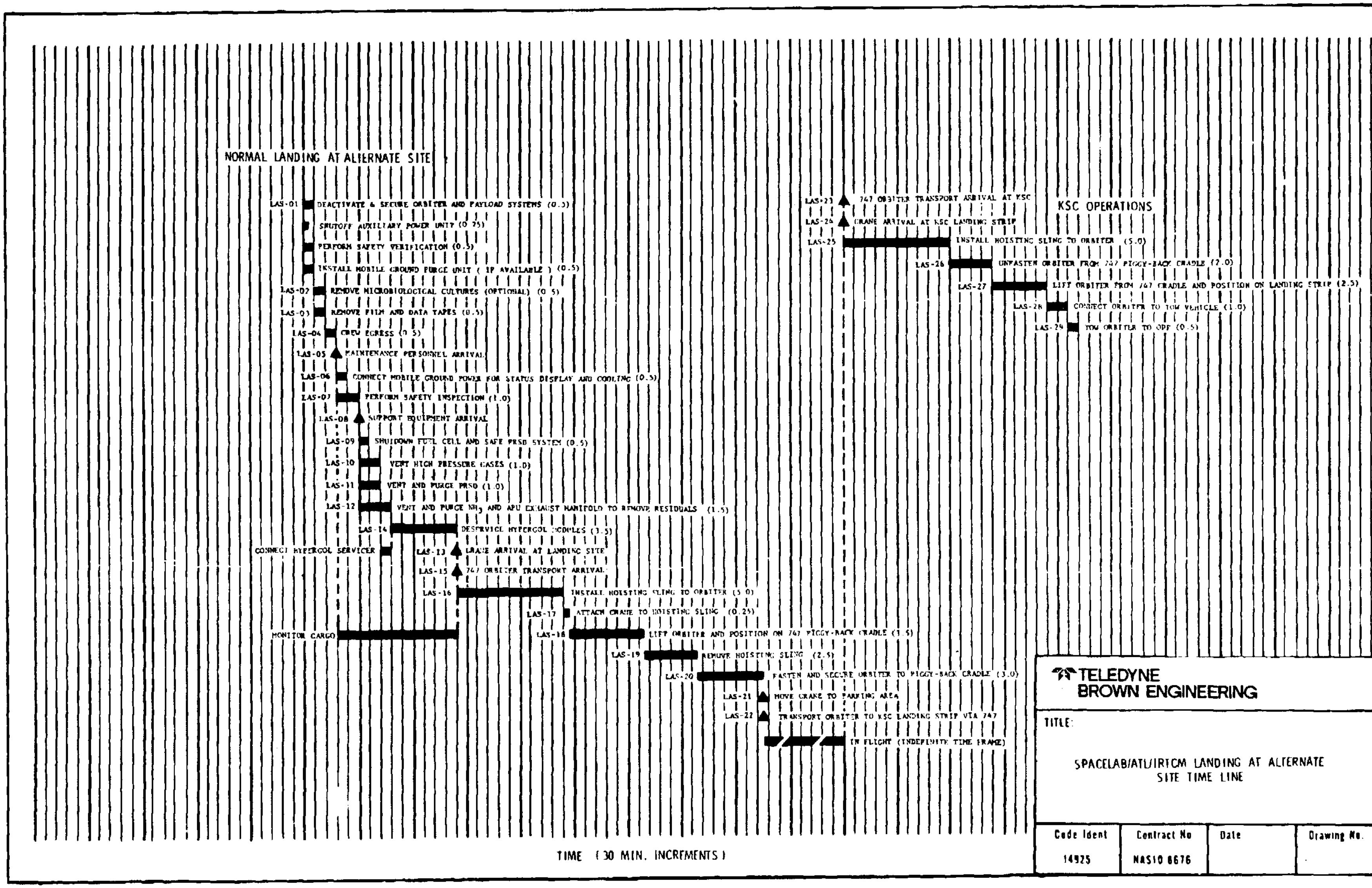

FIGURE 9. SPACELAB/ATL LANDING AT ALTERNATE SITE TIME LINE

22-A

3.1.4.2 Safing Requirements

Safing requirements for the Spacelab are performed in flight.

3.1.5 Crash/Shock Condition Landing at KSC

Crash/shock condition landing is a hard or rough landing with the potential of producing landing gear damages, hazardous leakages, etc., that could ultimately result in a critical or catastrophic condition. The precautions to be taken are similar to those required for aircraft forced to make an emergency landing. Rescue personnel and fire suppressant equipment should be ready on the landing strip in case of fire. Of primary concern in this contingency is crew evacuation. After crew evacuation, an inspection is made of the Orbiter's landing gear to determine its ability to be towed off the landing strip and to the OPF.

3.1.5.1 Time Line

The crash/shock landing at KSC contingency flow is shown in Figure 10. The time required from landing to transport to the OPF is indefinite based on the condition of the Orbiter and leakage of propellants or hazardous fluids. The time line is shown on Figure 11.

3.1.5.2 Safing Requirements

Safing requirements for the Spacelab are performed in flight.

3.1.6 Crash/Shock Condition Landing at a Contingency Site

The same basic assumptions that applied for landing at a contingency site and crash/shock condition landing at KSC are also applicable for this contingency. This contingency plan allows for a waiting period if severe leakages were sustained prior to continuing with the safing activities. This is an indeterminate time period and, depending upon the severity of the leakages and the type of materials, may require a different sequence of events.

3.1.6.1 Time Line

The crash/shock condition landing at a contingency site flow is shown in Figure 12. The time required from landing

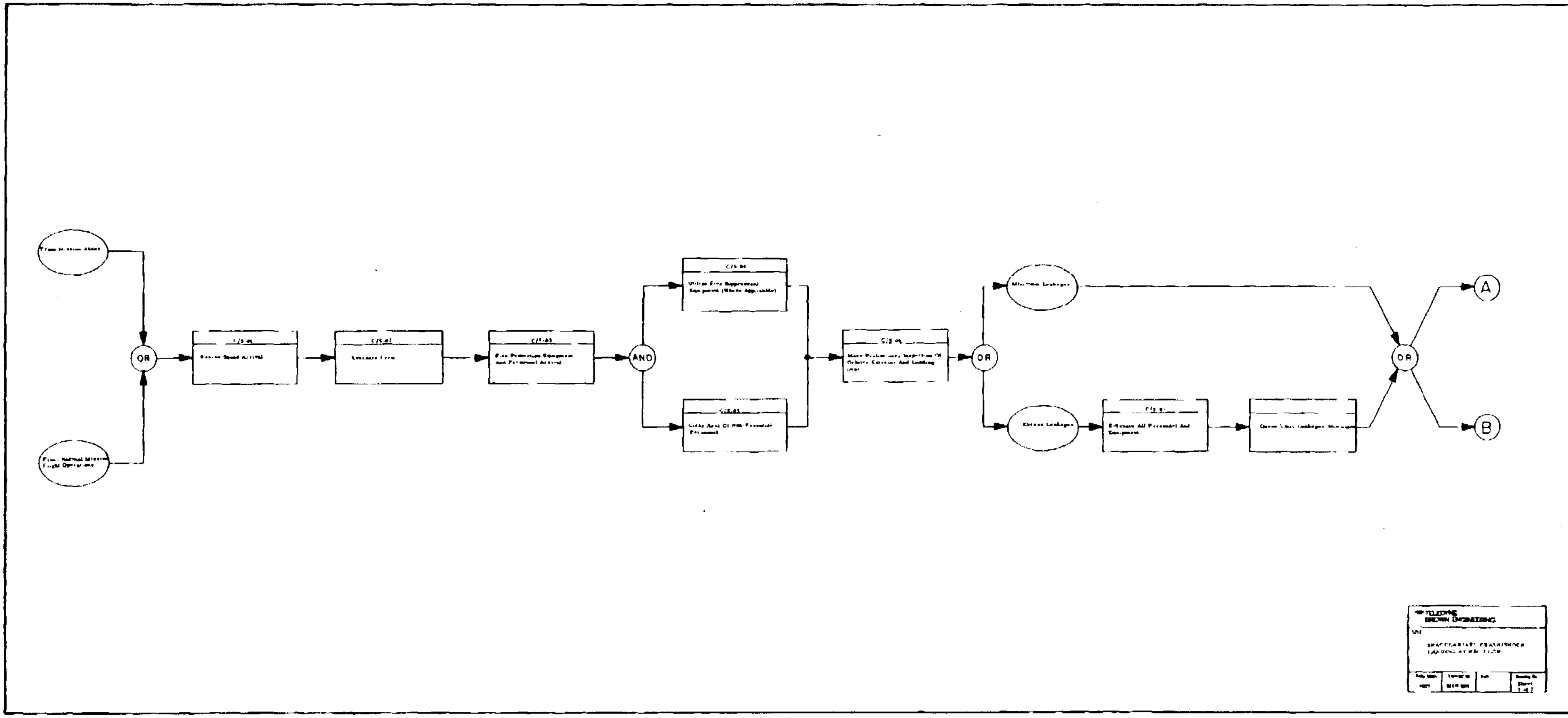

FIGURE 10. SPACELAB/ATL CRASH/SHOCK LANDING AT KSC FLOW (SHEET 1 of 2)

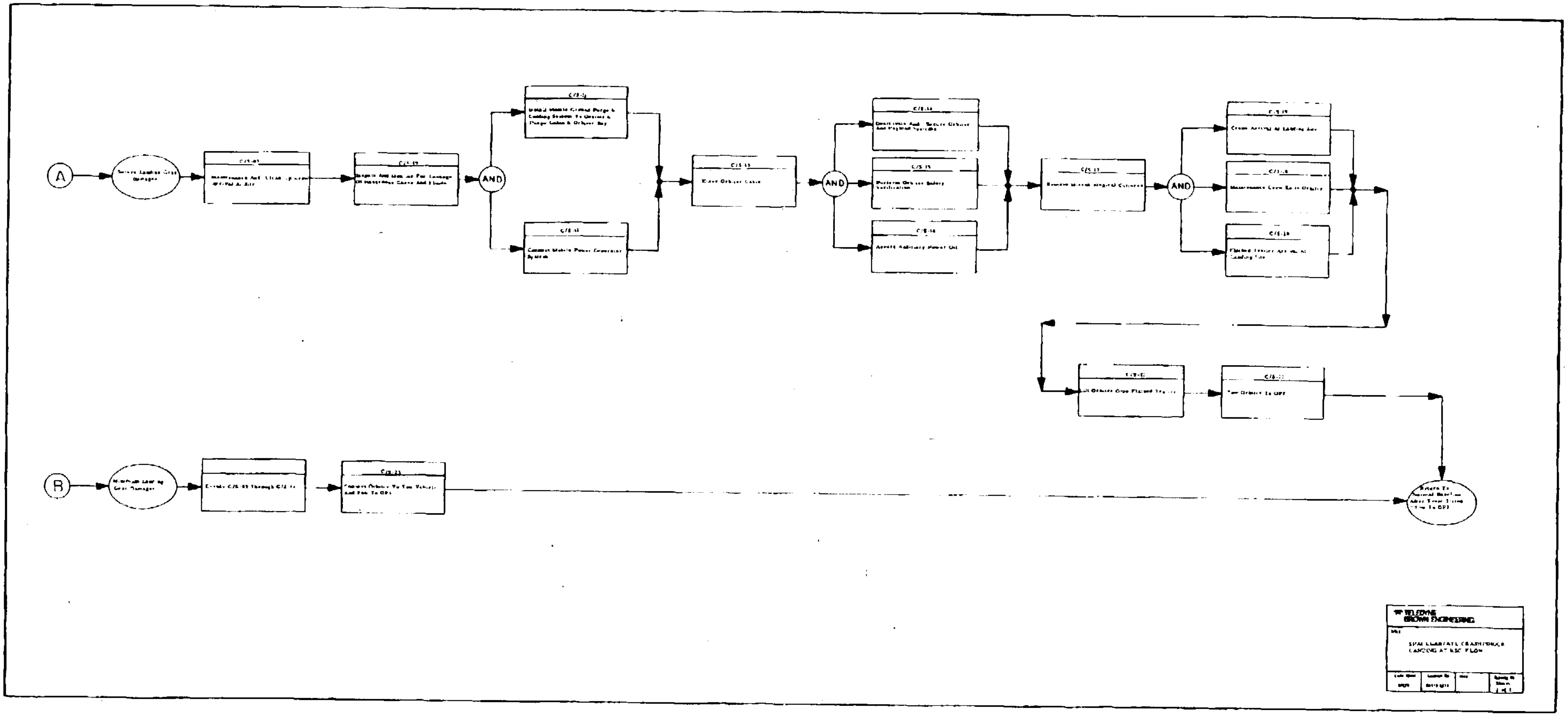

FIGURE 10. SPACELAB/ATL CRASH/SHOCK LANDING AT KSC FLOW (SHEET 2 of 2)

25 - A

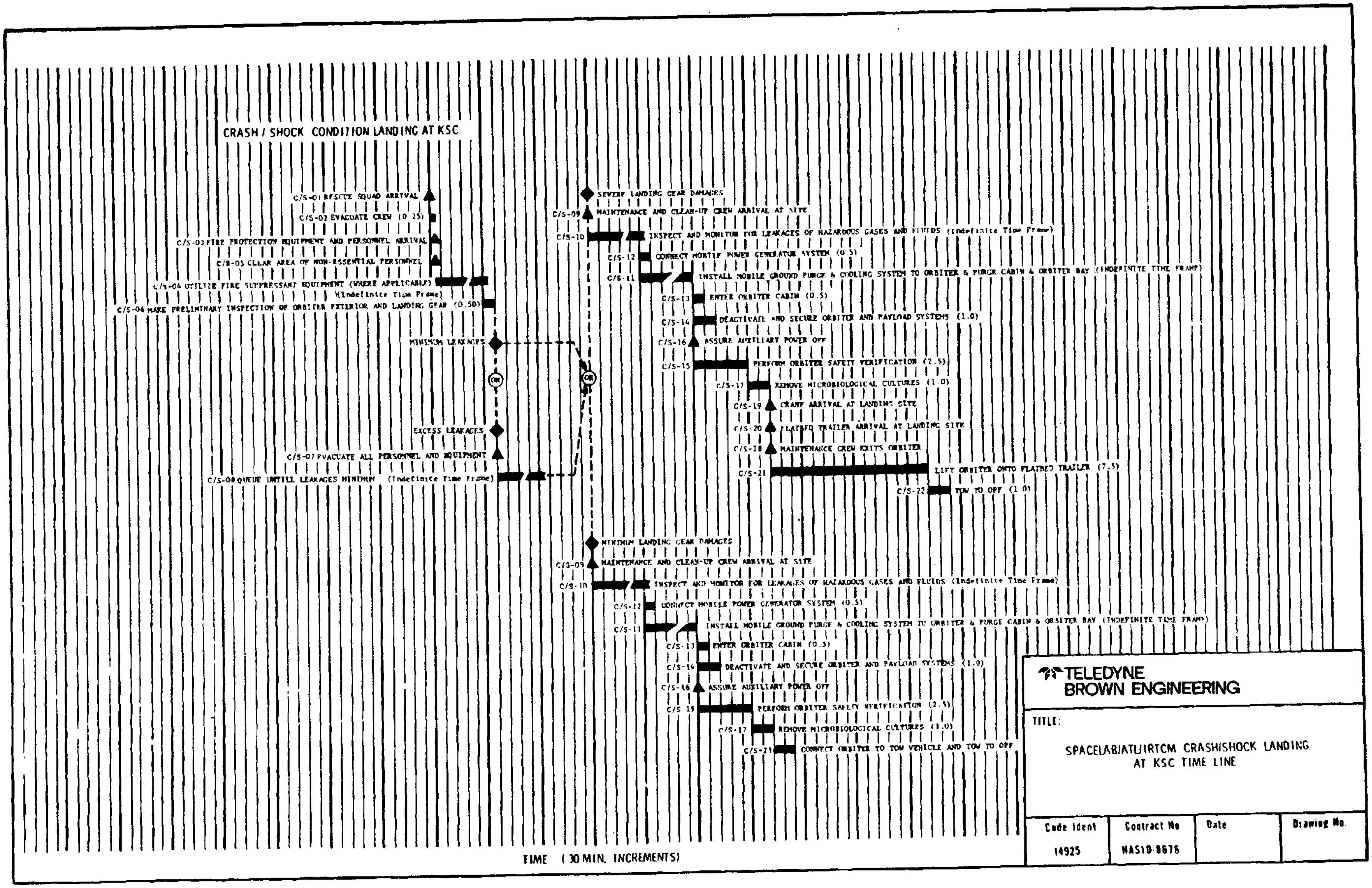

FIGURE 11. SPACELAB/ATL CRASH/SHOCK LANDING AT KSC TIME LINE

26-A

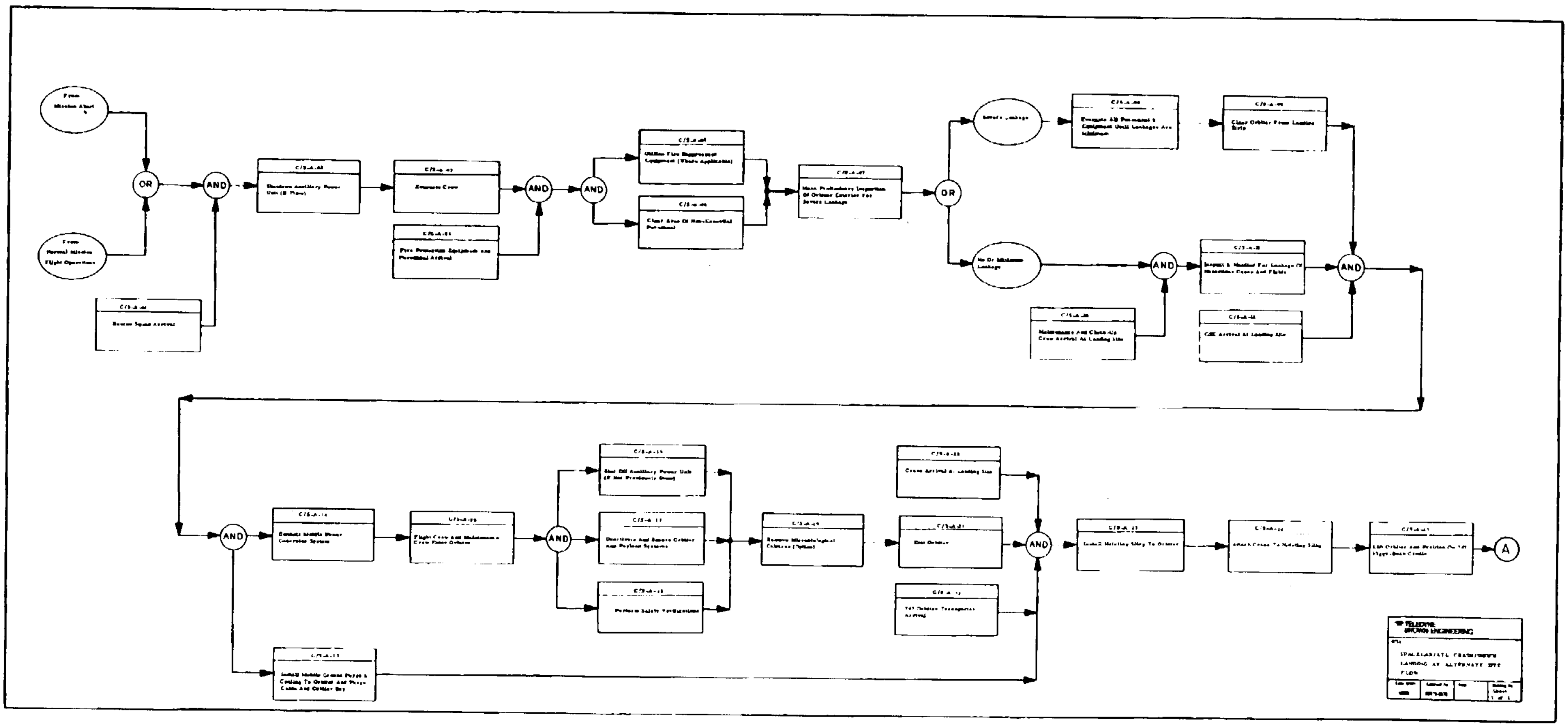

FIGURE 12. SPACELAB/ATL CRASH/SHOCK LANDING AT ALTERNATE SITE FLOW (SHEET 1 of 2)

27-A

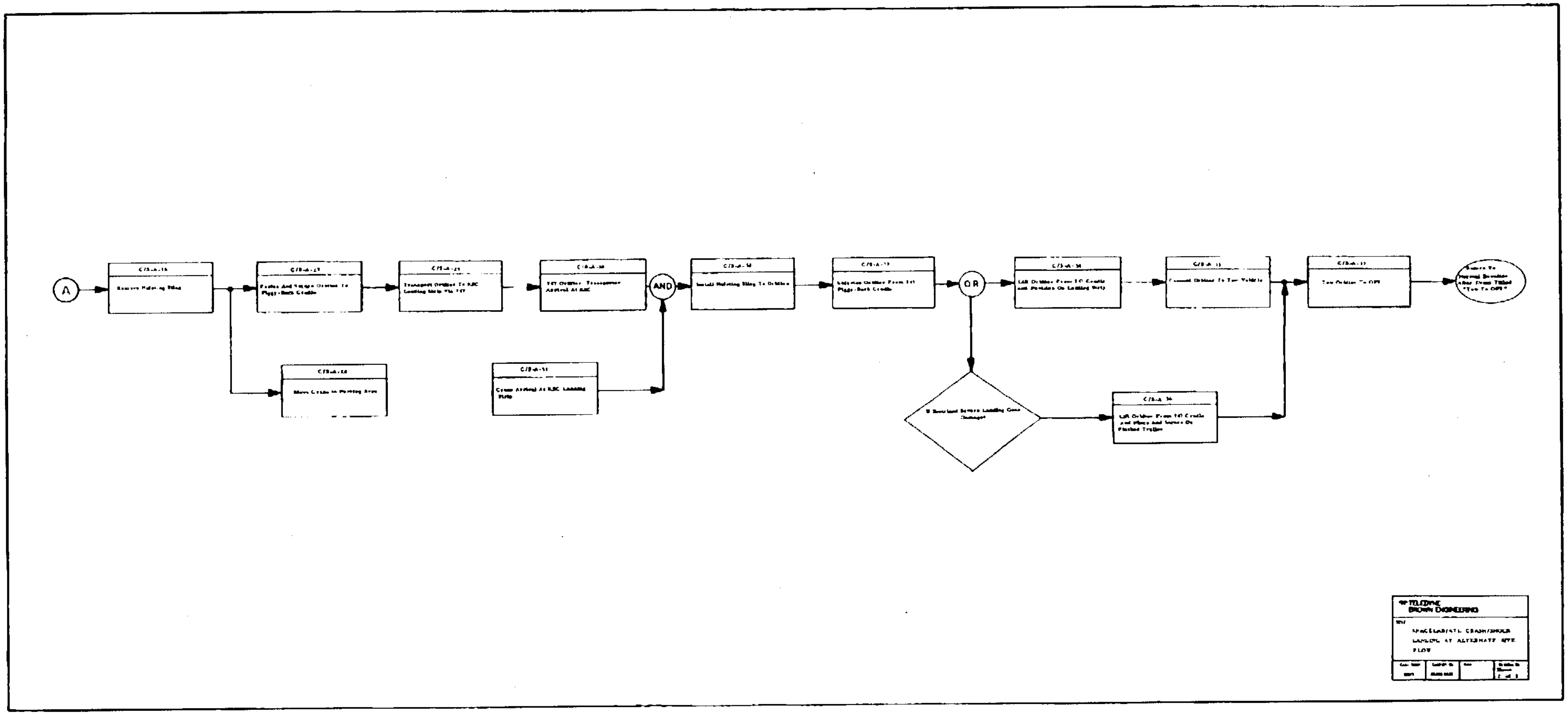

FIGURE 12. SPACELAB/ATL CRASH/SHOCK LANDING AT ALTERNATE SITE FLOW (SHEET 2 of 2)

28 - A

to transport to KSC depends upon the distance and time to arrival of personnel and equipment. The time line for this contingency is shown in Figure 13.

3.1.6.2 Safing Requirements

Safing requirements for the Spacelab are performed in flight.

3.2 TUG/SEPS/SEOS CARGO CONTINGENCY PLANS

3.2.1 Backout Operations

This contingency is a general flow applicable to any Tug cargo and makes no unique payload requirements. It is assumed that the reason for the backout is controlled. If a specific payload or cargo related cause were to be identified that required a fix or remedial action as a prerequisite to backout safety, it could be incorporated into this general flow. The operational steps required for this contingency are shown in Figure 14.

3.2.1.1 Time Line

The time line for the Tug/SEPS/SEOS backout operation is shown in Figure 15. The time required for safing and removal of the payload from initiation of contingency operations to return to SAEF #1 (TPF) is approximately 34 hr.

3.2.1.2 Safing Requirements

The following is a summary of constraints and safing requirements that must be performed during the backout operations.

- Drain and purge Tug LH_2, fuel cell H_2, and External Tank (ET) LH_2 through Orbiter umbilicals.
- Drain and purge Tug LOX, fuel cell O_2, and ET LOX through Orbiter umbilicals.
- Vent Tug LOX and LH_2 pressurants.
- Vent Orbiter Reaction Control Subsystem (RCS), Orbital Maneuvering System (OMS), and Accessory Power Unit (APU) pressurants; drain PSRD propellants.

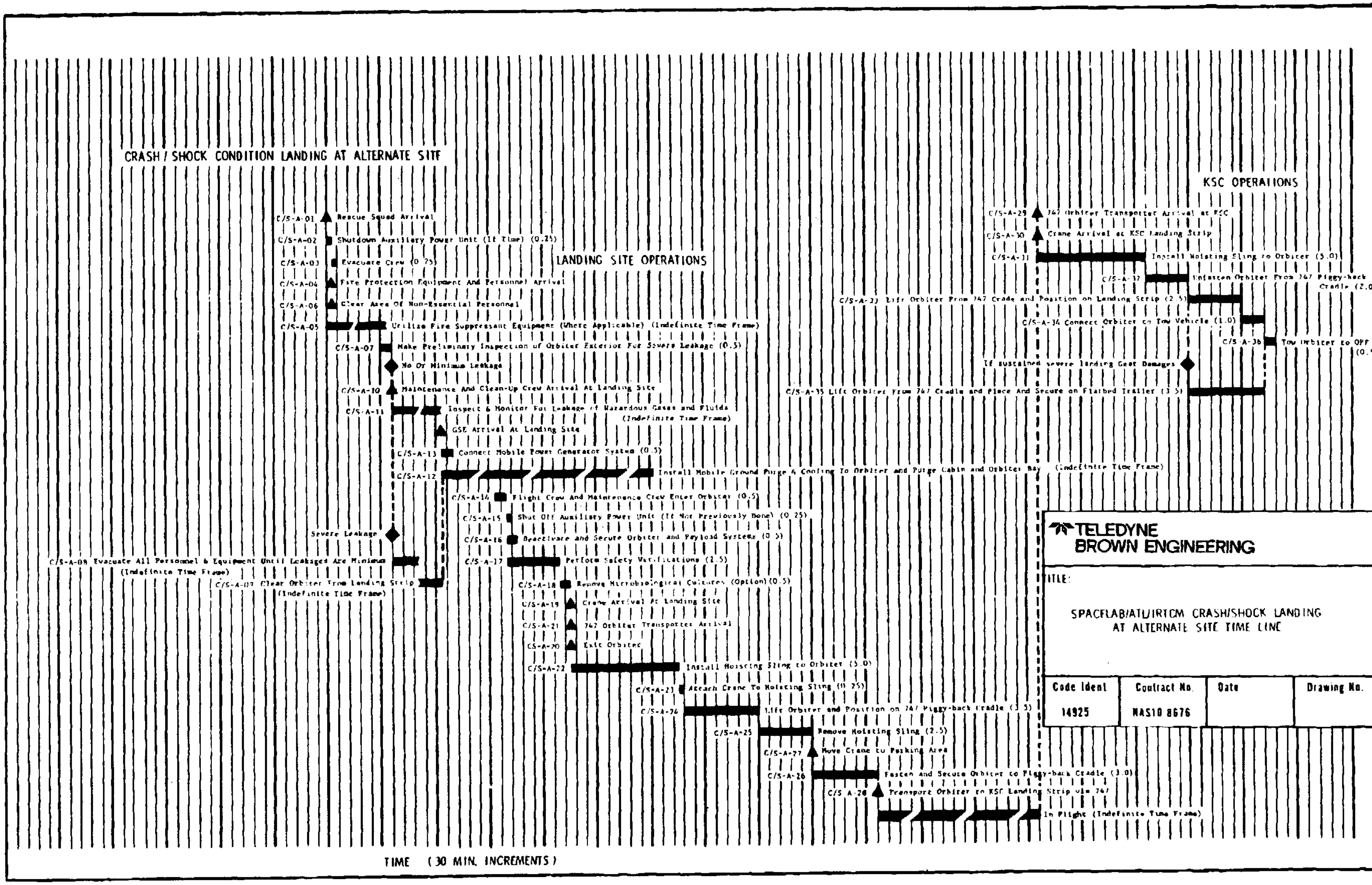

FIGURE 13. SPACELAB/ATL CRASH/SHOCK LANDING AT ALTERNATE SITE TIME LINE

30 - A

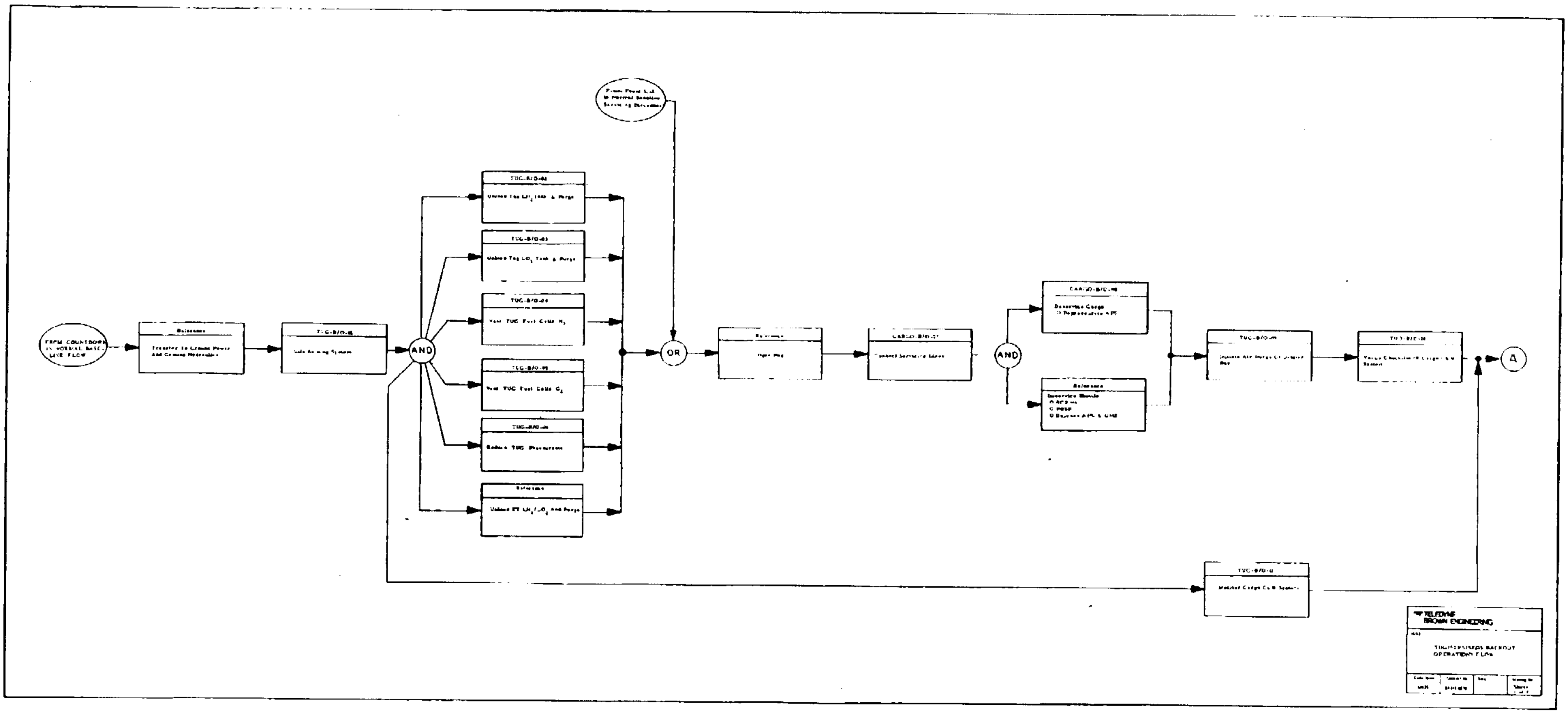

FIGURE 14. TUG/SEPS/SEOS BACKOUT OPERATIONS FLOW (SHEET 1 of 2)

31 A

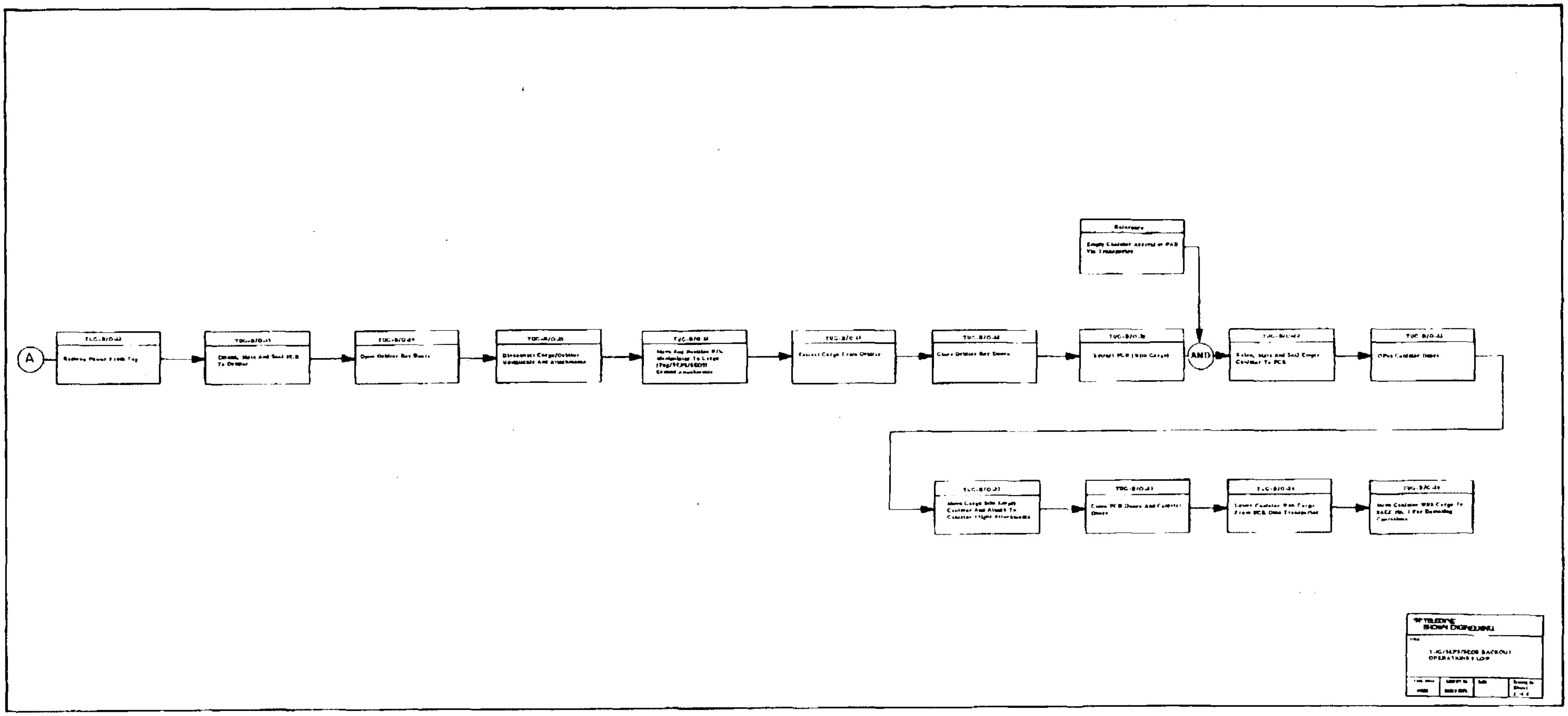

FIGURE 14. TUG/SEPS/SEOS BACKOUT OPERATIONS FLOW (SHEET 2 of 2)

32- A

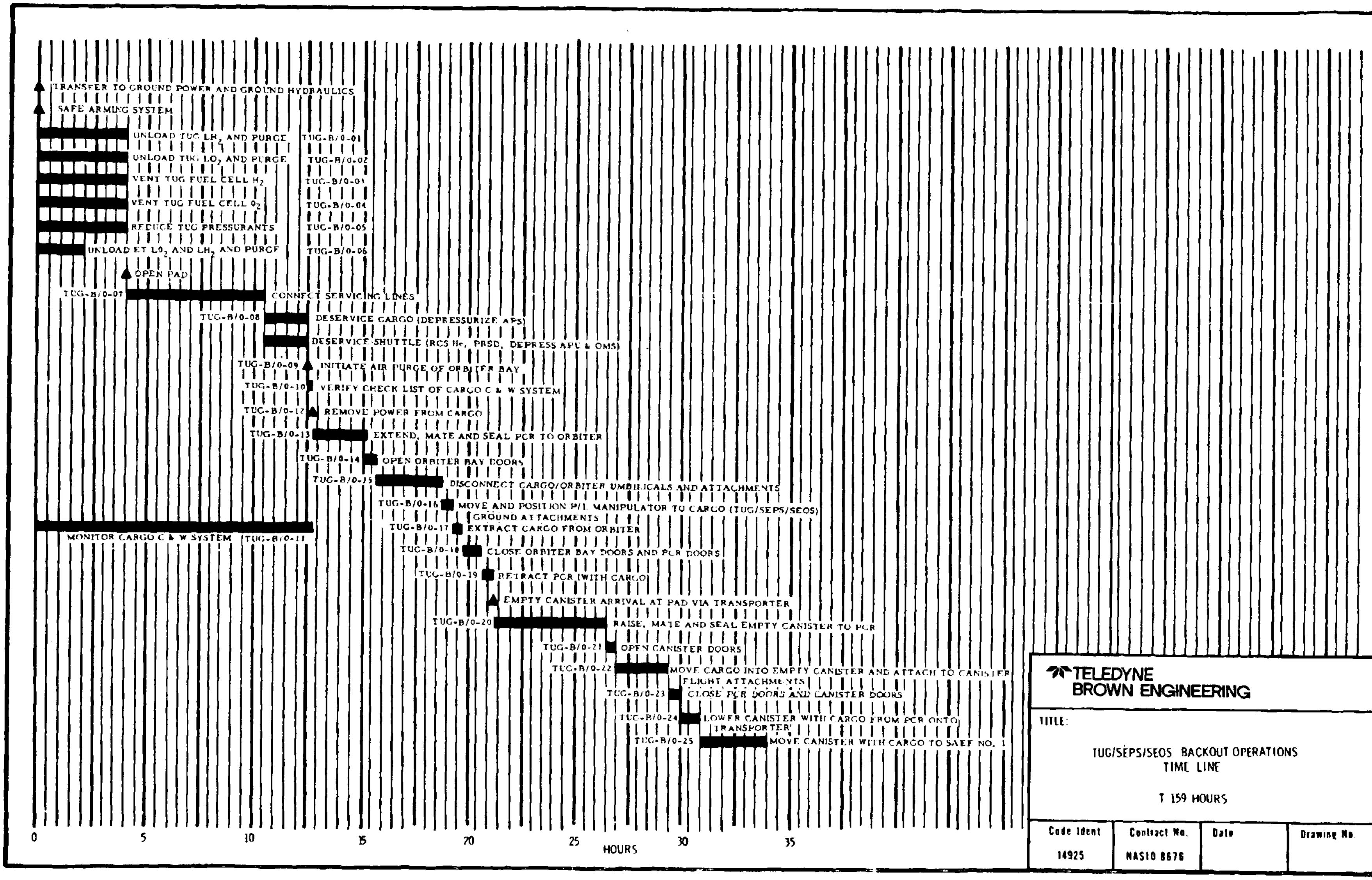

FIGURE 15. TUG/SEPS/SEOS BACKOUT OPERATIONS TIME LINE

- Connect service lines and vent Tug, SEPS, and SEOS APS pressurants; vent SEPS Main Propulsion System (MPS) pressurants.

- Verify that no hazardous gases are present in the cargo bay. The variety of hazardous materials (LH_2, LOX, hydrazine, mercury) indicates the need for a hazardous gas analyzer in the cargo bay (at the pad).

- Verify checklist of cargo control and warning system and remove payload power.

- Separation of the SEOS or the SEPS/SEOS requires safing of separation ordnance and installation of shorting plugs. This operation requires access from the PCR to all cargo pyrotechnic initiating devices and may severely impact the payload design. The same access is required for attaching the changed out payloads to the Tug or the Tug/SEPS.

3.2.2 Vertical Changeout at the Pad

This contingency covers the safing of the Shuttle and cargo and addresses three options:

- Assumes a malfunction or accident, etc., has occurred requiring that the SEOS be changed out.

- Shows a changeout of the SEPS/SEOS assembly.

- Examines the option of changing out the entire Tug/SEPS/SEOS cargo.

The last option did not consider the requirement of the payload change-out room having the capability of handling two cargoes simultaneously because this problem was addressed in the IUS/F_2PU/PJP cargo.

The operational steps required for this contingency operation are shown in Figure 16. This vertical changeout contingency is initiated prior to servicing disconnect. If this contingency is initiated later in the processing flow, a reconnect of the Orbiter and payload service umbilicals would be required. The pad is cleared during propellant drain operations.

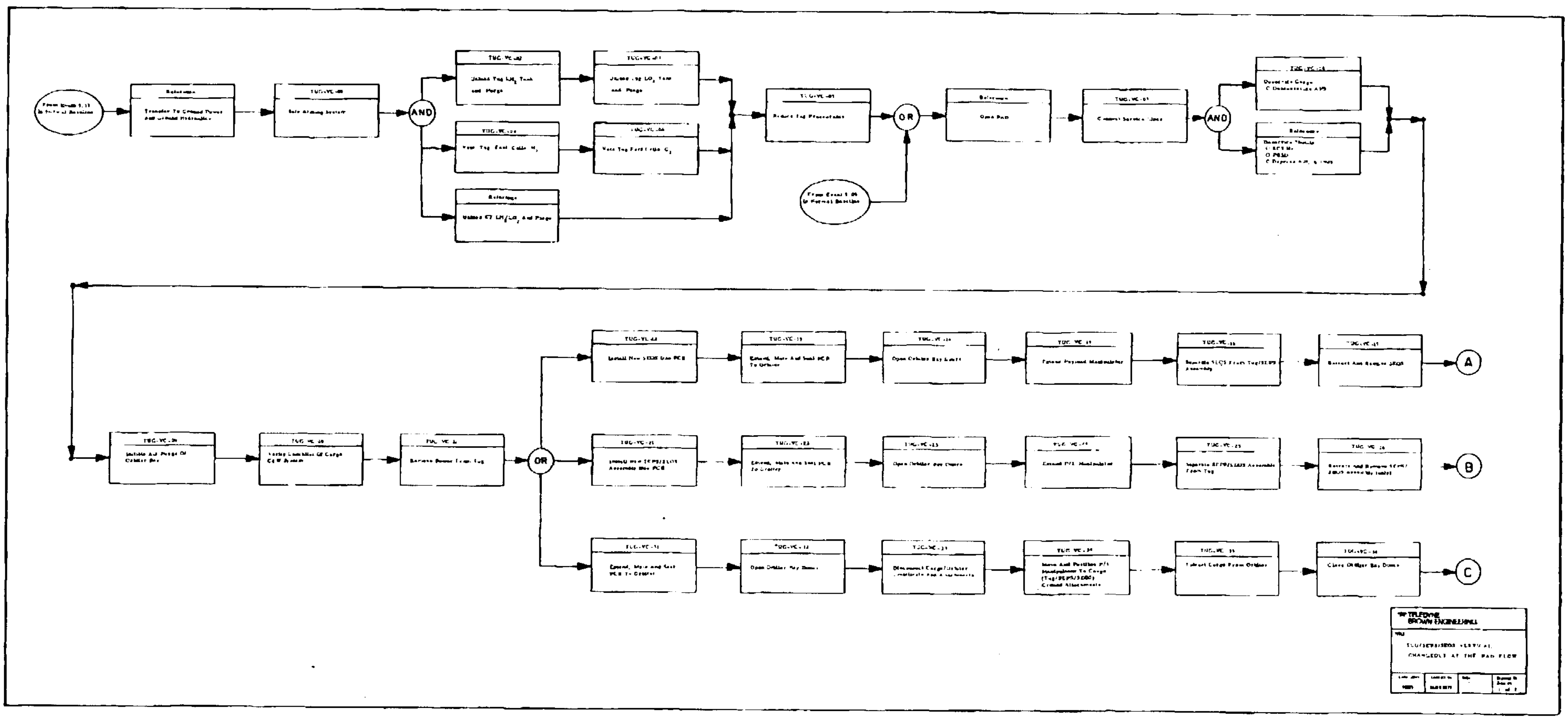

FIGURE 16. TUG/SEPS/SEOS VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 1 of 2)

35-A

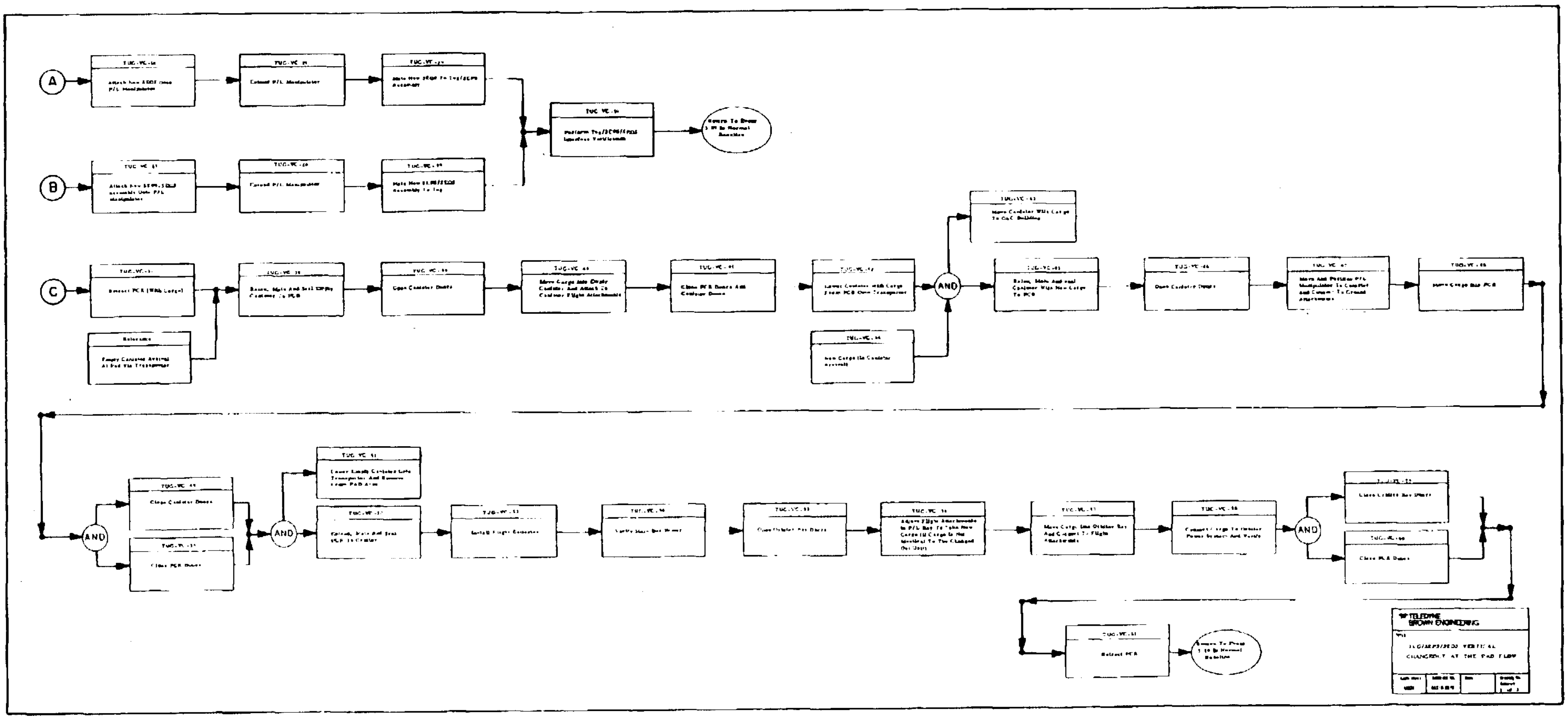

FIGURE 16. TUG/SEPS/SEOS VERTICAL CHANGEOUT AT THE PAD FLOW

(SHEET 2 of 2)

36 - A

3.2.2.1 Time Line

The time line for the Tug/SEPS/SEOS vertical changeout contingency is shown in Figure 17. If the SEOS payload is changed out, the time from initiation of the contingency operation to return to normal processing is approximately 32 hr. If the SEPS/SEOS payloads are changed out together, the time from initiation of the contingency operation to return to normal processing is approximately 32 hr. If the Tug/SEPS/SEOS cargo is changed out, the time from initiation of the contingency operation to launch of a new cargo is approximately 80 hr.

The time lines for changeout of the SEOS only and the SEPS/SEOS assume that the new payloads are at the pad when the contingency operations are initiated. The time line for changeout of the Tug/SEPS/SEOS cargo requires retraction and extension of the Payload Changeout Room (PCR) twice.

3.2.2.2 Safing Requirements

Safing requirements for the Tug/SEPS/SEOS vertical changeout contingency are identical to those for the Tug/SEPS/SEOS backout operations except that the pyrotechnics need not be removed but only safed and shorting plugs installed.

3.2.3 Mission Abort

The mission abort contingency plan for the Tug/SEPS/SEOS cargo is shown in Figure 18. The majority of the operational steps called out are monitoring and control functions of the Tug. The required operations for a mission abort of this cargo need further definition and additional study. A summary of the findings of this contingency analysis is as follows:

- A rough cut analysis of the cargo weights when only Tug LOX and LH_2 are dumped indicate that the cargo center of gravity is within the Shuttle envelope requirements and total weight requirements for landing. Therefore, Mercury dumping is not required because of weight and cargo center of gravity limitations.

- Since this cargo is attached to the Shuttle by the Tug only, the cantilever effects on the Tug structure and adapter attach points at landing should be evaluated to take into account the momentum shift of the 3000 lb of mercury.

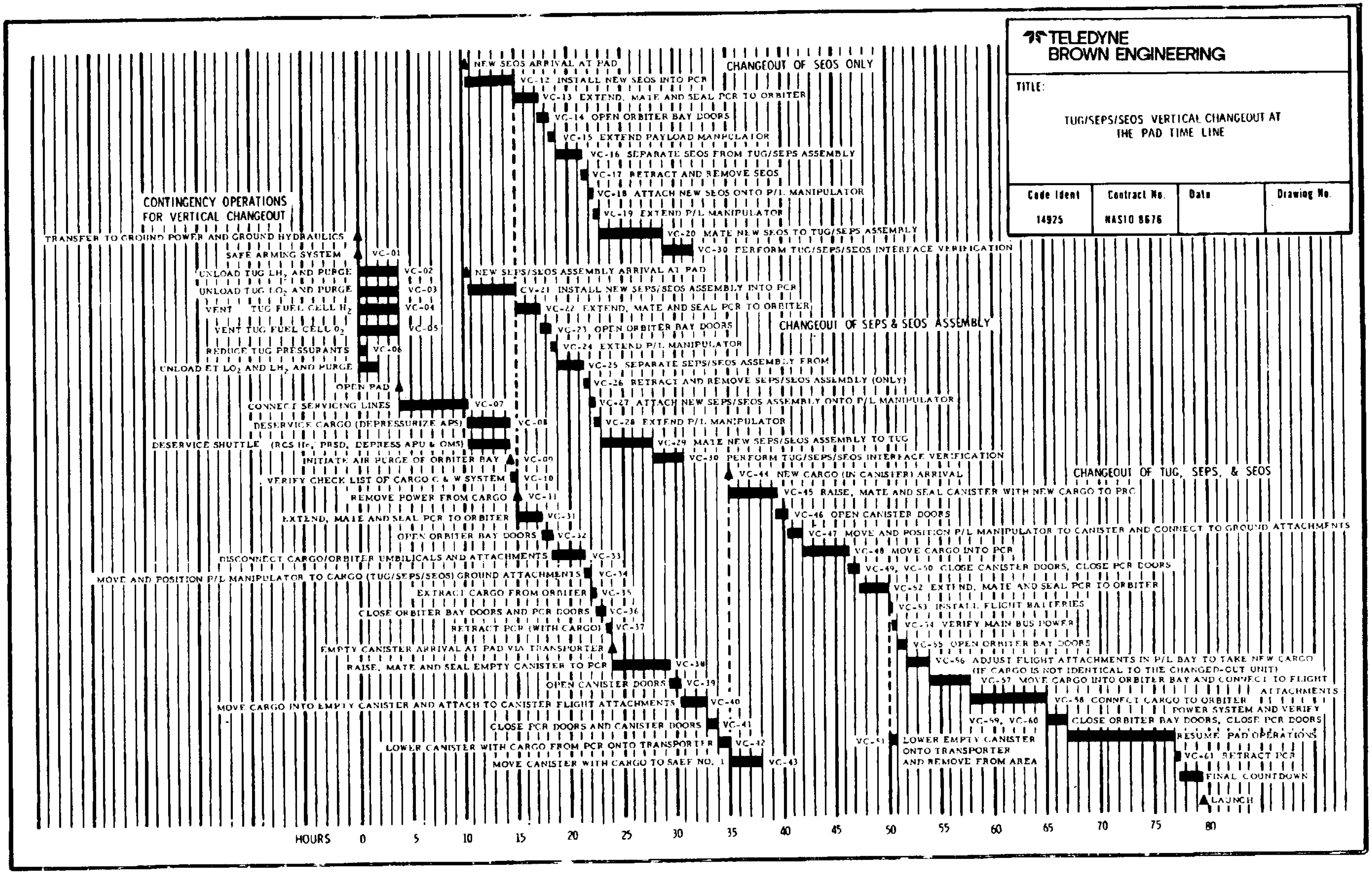

FIGURE 17. TUG/SEPS/SEOS VERTICAL CHANGEOUT AT THE PAD TIME LINE

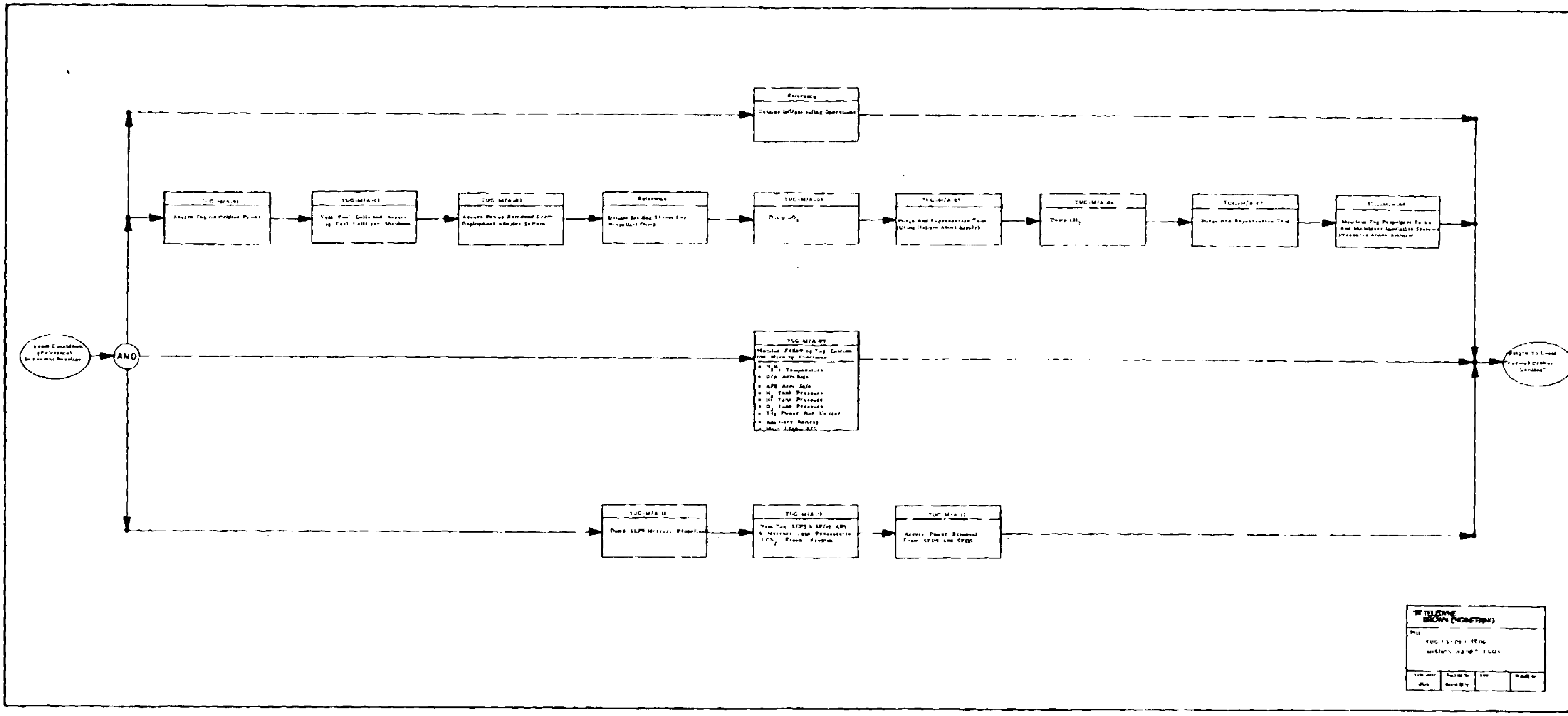

FIGURE 18. TUG/SEPS/SEOS MISSION ABORT FLOW

- Dump the Mercury if the momentum shift of the 3000 lb of Mercury has not been taken into account.

- If the design is such that in-flight dumping is not required, Mercury tanks should remain pressurized or be pressurized to the operating level to assist in maintaining the Mercury tank bladder integrity. Design of the tanks in an "upside down" configuration would relieve stress on the tank bladders at landing but would subject the bladders to liftoff "g" loads. The design of the mercury tanks should minimize the ullage volume.

- A study should be performed to determine the effect of a mercury cloud/dispersion on the atmosphere and ecology.

- Alternate methods of dumping, optimum particle droplet size, and time for dumping should be further studied az the development of the SEPS kick stage progresses.

3.2.3.1 Time Line

A nominal time line for the mission abort contingency operations is shown in Figure 19. The dumping of mercury is shown as an option with no time specified.

3.2.3.2 Safing Requirement

Safing requirements shown in the contingency flow include:

- Tug LOX and LH_2 tanks are dumped out through the T-O umbilical, purged, and partially repressurized for landing. The Tug LH_2 tank is vented and purged at the landing strip (normal operation).

- From a Shuttle safety standpoint, it is desirable to dump the mercury propellant. However, the effects of this action need to be determined as to the effect on the ecology.

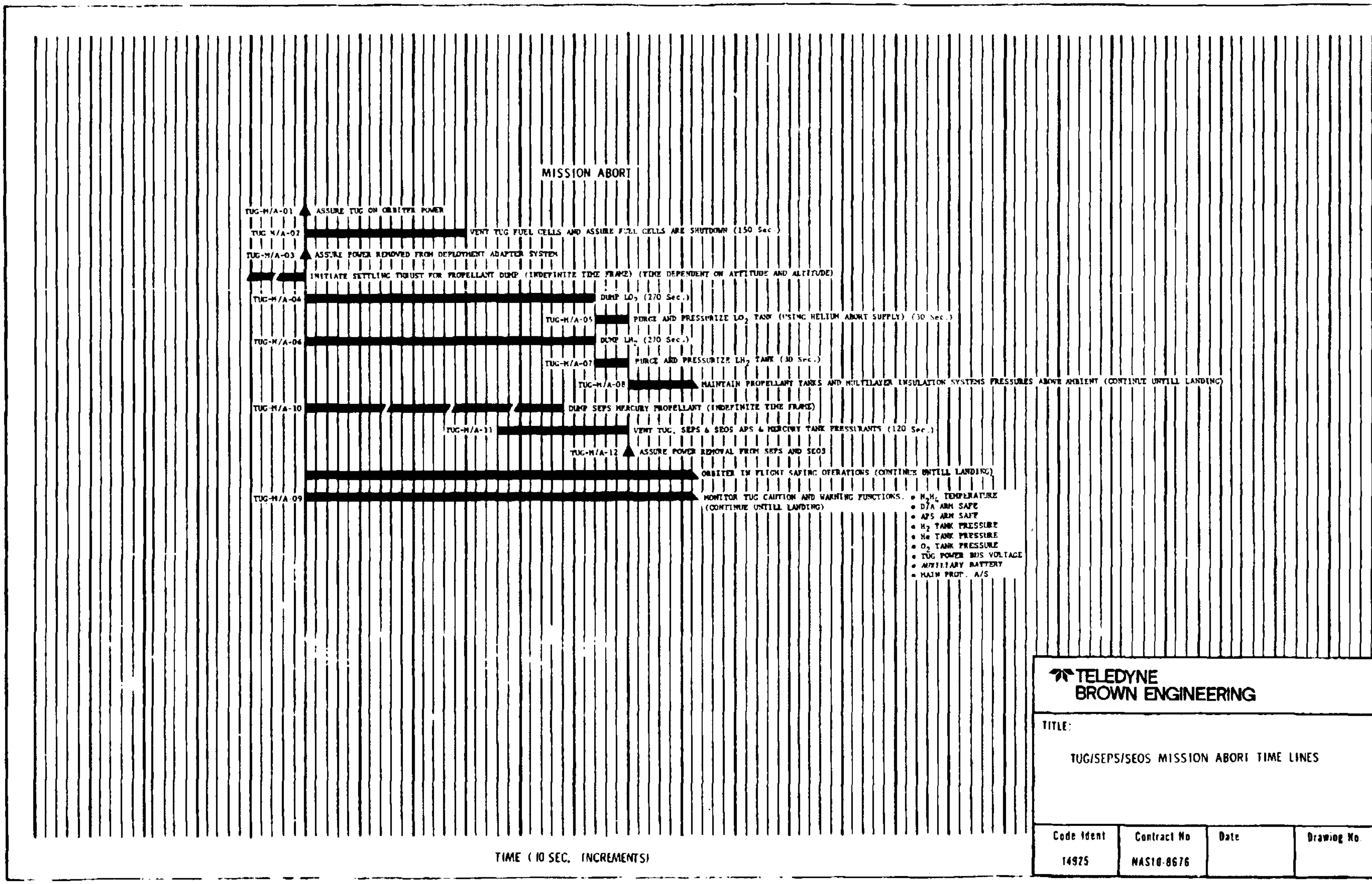

FIGURE 19. TUG/SEPS/SEOS MISSION ABORT TIME LINES

- All SEPS and SEOS pressurants (APS and MPS) should be vented and Tug fuel cell O_2/H_2 bottles vented but still maintain a positive pressure.

3.2.4 Normal Landing at a Contingency Site

Due to Orbiter constraints, very little can be done to the Tug cargo for this contingency plan. The decision to land at a contingency site may or may not be a result of a prior mission abort. If landing at a contingency site had been preceded by a mission abort, then the Lox and LH_2 would have been dumped, the tanks purged, as well as the multilayer insulation purged, just as during a normal flight.

3.2.4.1 Time Line

The normal landing at a contingency site flow is shown in Figure 20. The time required to safe and prepare the Orbiter and payload for transport to KSC depends upon the distance and time to arrival of maintenance personnel and support equipment. The time line for this contingency is shown in Figure 21.

3.2.4.2 Safing Requirements

The following constraints and Tug safing requirements for normal landing at a contingency site are:

- Monitor cargo caution and warning functions.
- Vent hydrogen.
- Additional helium purge of propellant tanks and Multilayer Insulation (MLI).

These Tug safing requirements are performed in conjunction with the following Orbiter activities:

- Perform Safety Verification
- Deactivate and secure Orbiter.
- Shut Off Auxiliary Power Unit.
- Install Mobile Ground Purge Unit.

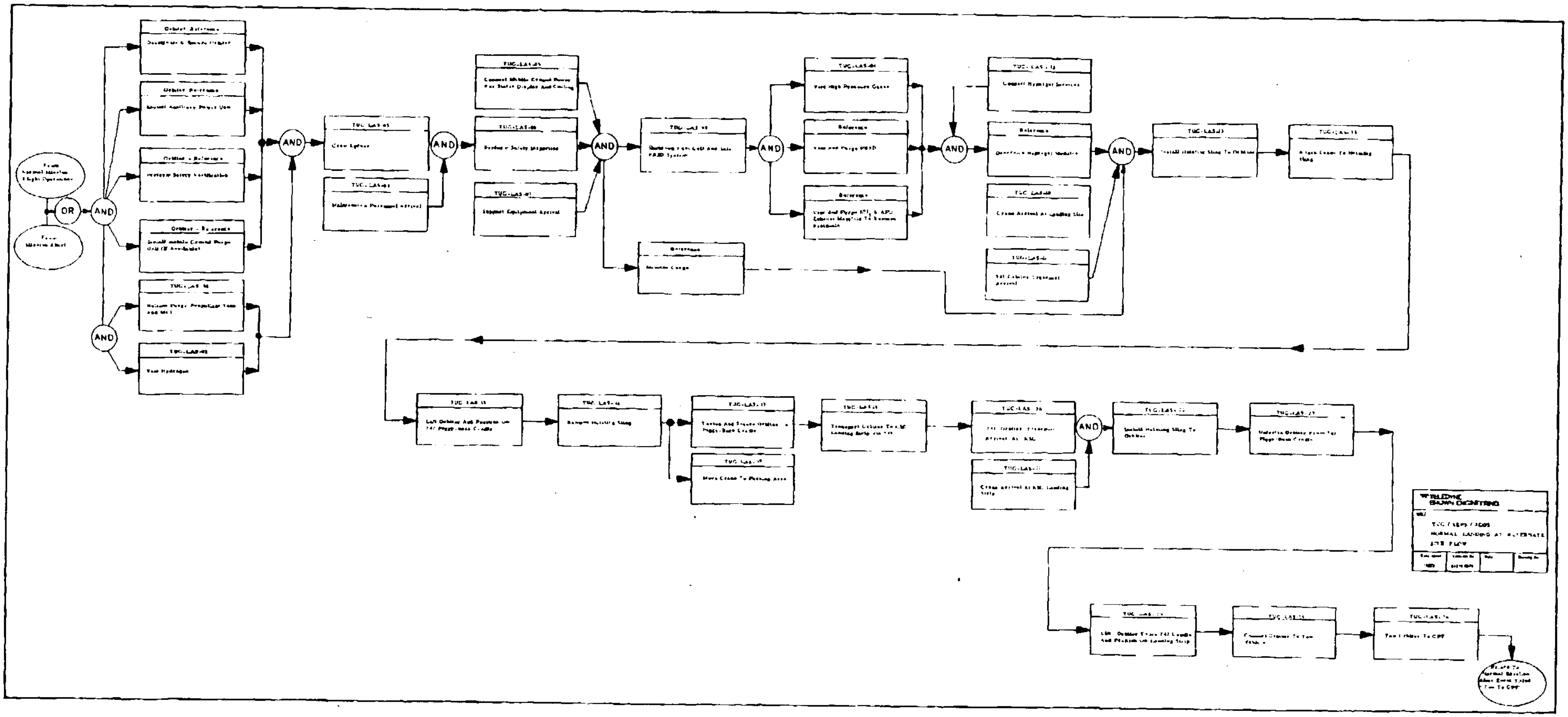

FIGURE 20. TUG/SEPS/SF.OS NORMAL LANDING AT ALTERNATE SITE FLOW

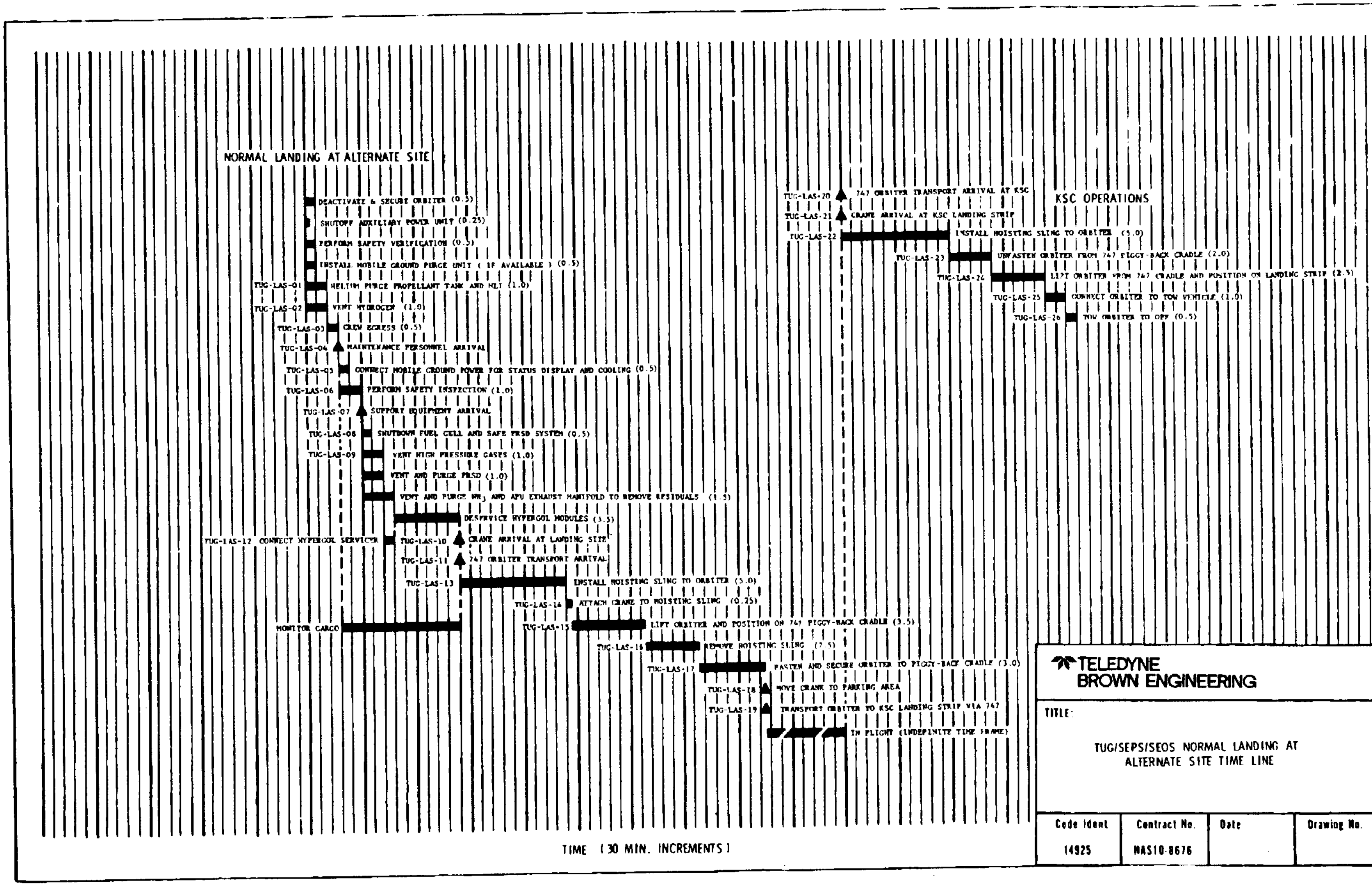

FIGURE 21. TUG/SEPS/SEOS NORMAL LANDING AT ALTERNATE SITE TIME LINE

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After mobile ground power for status display and cooling has been connected, the following operations are performed while cargo monitoring is continued:

- Fuel cells shut down and vented.
- High pressure gases are vented.
- NH_3 OMS and APU exhaust manifold are vented and purged.
- Modules are deserviced.

3.2.5 Crash/Shock Condition Landing at KSC

Crash/shock condition landing is a hard or rough landing with the potential of producing landing gear damages, hazardous leakages, etc., that could ultimately result in a critical or catastrophic condition. With the exception of landing gear damages, the most hazardous damage would primarily be internal and may not be detected through the caution and warning system until they had progressed to a potentially critical or catastrophic condition. Once the crash/shock condition has been sustained, the crew's safety is paramount and crew evacuation would be the immediate requirement.

3.2.5.1 Time Line

The crash/shock condition landing at KSC contingency flow is shown in Figure 22. The time required from landing to transfer to the OPF is an indefinite time frame and is based upon the following:

- Condition of the Orbiter
- Leakage of propellants or hazardous fluids.

The time line for this contingency plan is shown in Figure 23.

3.2.5.2 Safing Requirements

Safing requirements for this contingency plan are primarily Orbiter related. Prior to Orbiter cabin reentry, safing activities consist of the following actions and precautions:

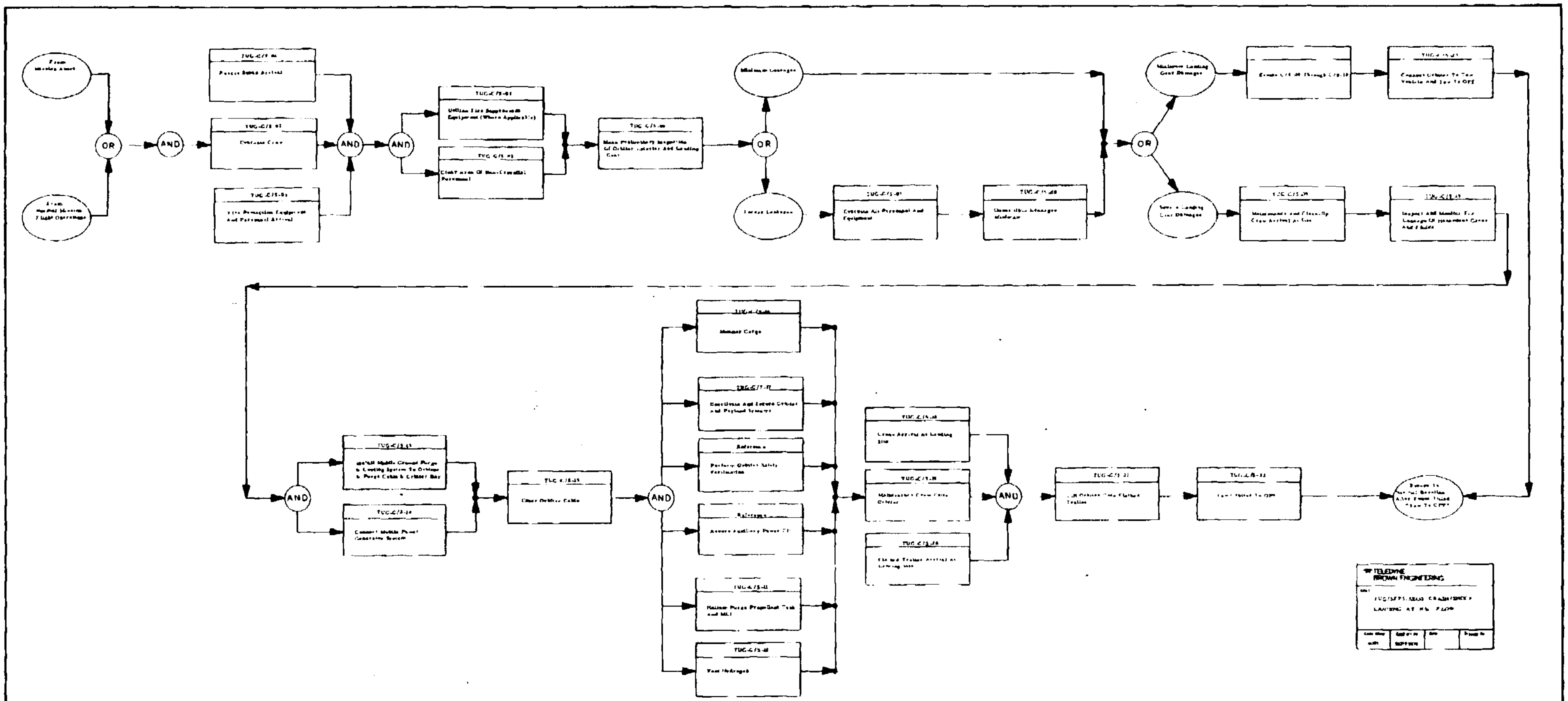

FIGURE 22. TUG/SEPS/SEOS CRASH/SHOCK LANDING AT KSC FLOW

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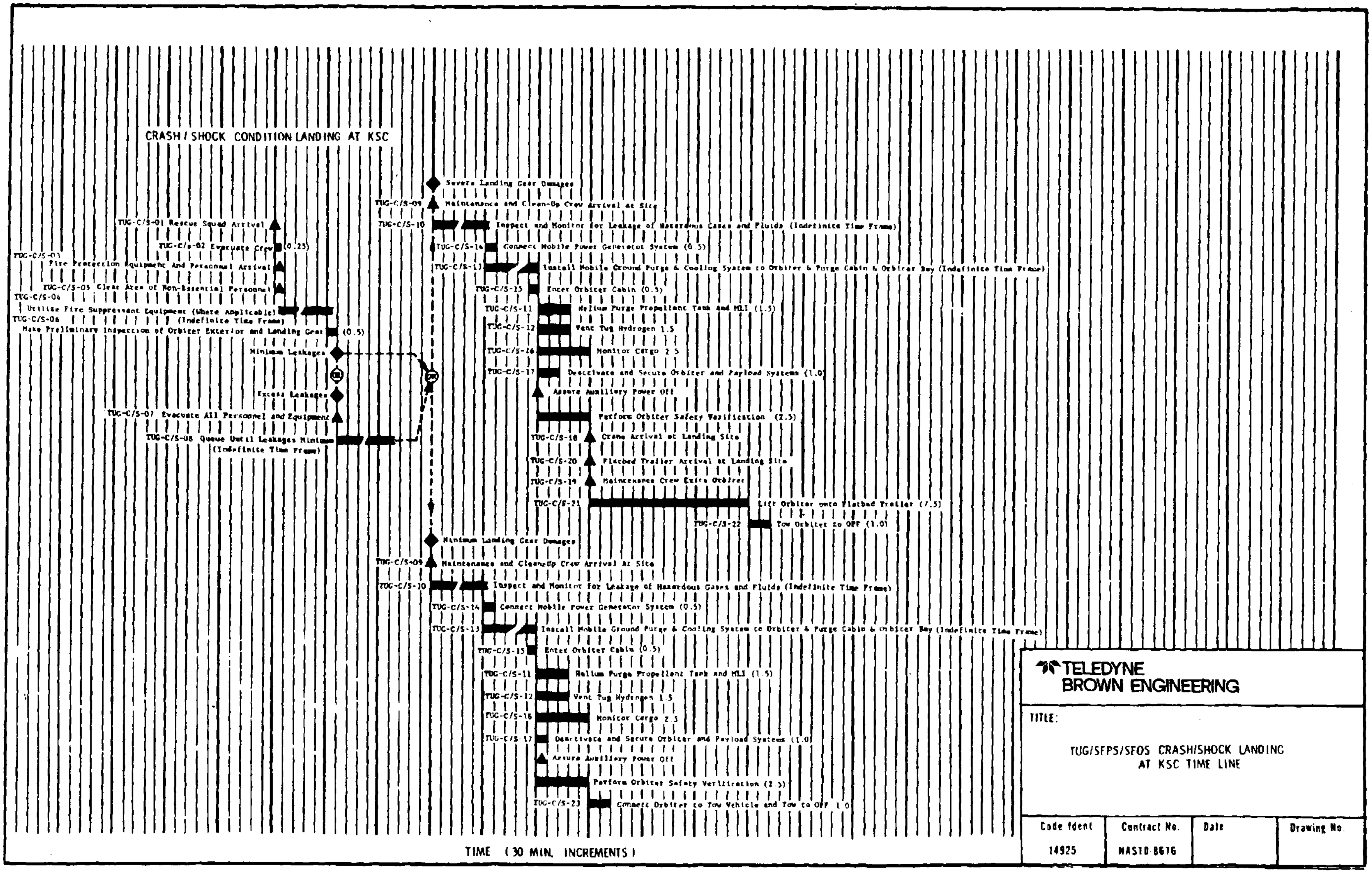


FIGURE 23. TUG/SEPS/SEOS CRASH/SHOCK LANDING AT KSC TIME LINE

- Evacuate crew
- Use fire suppressants where applicable
- Perform preliminary Orbiter inspection
- Inspect and monitor for hazardous materials leaks.

After reentry to the Orbiter, the following operations are performed while the cargo is monitored:

- Ensure that all Orbiter and payload systems have been deactivated and secured.
- Perform Orbiter safety verification.
- Ensure that auxiliary power is off.
- Vent Tug main propellant tanks
- Helium purge Tug propellant tanks and MLI.

3.2.6 Crash/Shock Condition Landing at Contingency Site

This contingency differs from the crash/shock condition landing at KSC in a very important aspect--a landing at a contingency site imposes a new set of constraints on the Orbiter and cargo. The equipment required to perform a rudimentary level of safing is not available at the contingency site and must be flown in; the time element involved presents a hazard to the Orbiter and cargo. Also, any damages sustained may not be as accurately assessed and treated as they should be, thus compounding the inherent hazard associated with transporting the cargo back to KSC.

3.2.6.1 Time Line

The crash/shock condition landing at a contingency site flow is shown in Figure 24. The time required from landing to transport to KSC depends upon the distance of the contingency site from KSC and, hence the time to arrival of personnel and essential equipment. The time line for this contingency plan is shown in Figure 25.

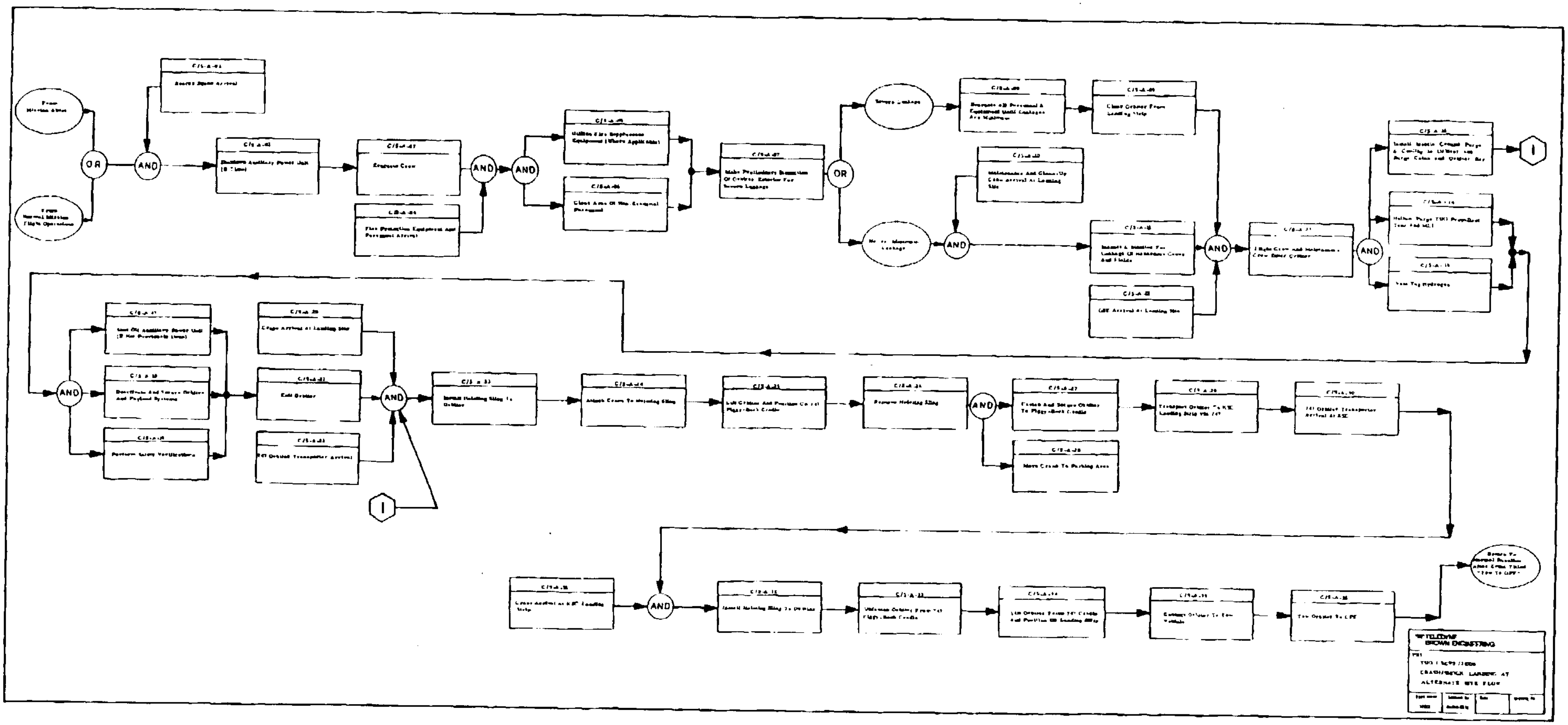


FIGURE 24. TUG/SEPS/SEOS CRASH/SHOCK LANDING AT ALTERNATE SITE FLOW

49- A

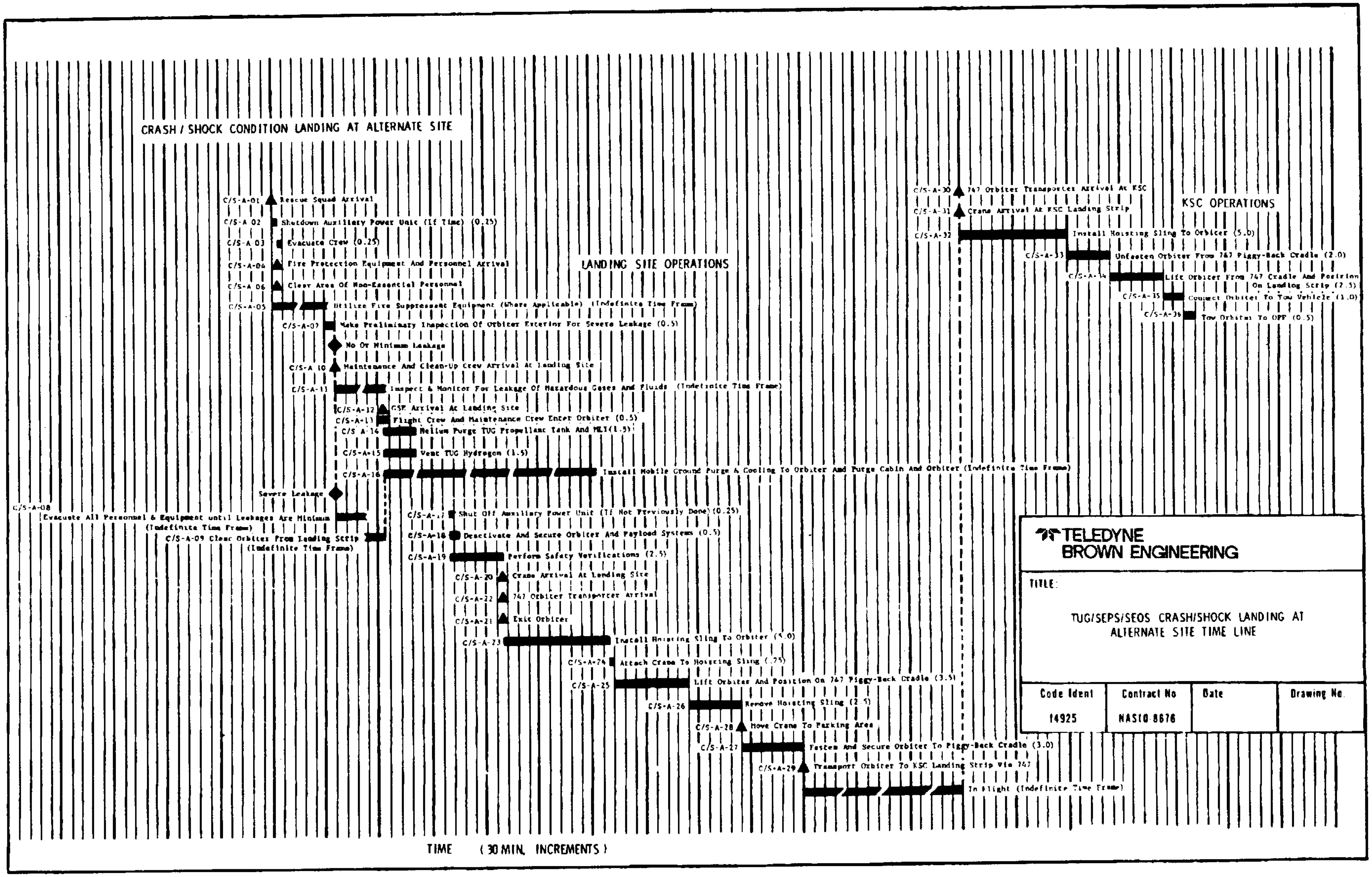


FIGURE 25. TUG/SEPS/SEOS CRASH/SHOCK LANDING AT ALTERNATE SITE TIME LINE

3.2.6.2 Safing Requirements

The following Tug safing requirements are:

- Vent Tug main propellant tanks
- Helium purge Tug propellant tanks and MLI.

3.3 IUS/F_2PU/PJP CARGO CONTINGENCY PLANS

3.3.1 Backout Operations at the Pad

The backout operations for the IUS/F_2PU/PJP cargo, like the normal processing of this cargo, present a number of unique situations and hazards. Two of these hazards and their impact are:

- The RTG's on the PJP payload present a radiological hazard that requires that the number of personnel and access to the cargo be limited. The RTG's also present a high temperature hazard if cooling is lost while in the cargo bay. A significant temperature rise in the cargo bay could adversely affect the thermal balance of the liquid fluorine oxidizer on the F_2PU. Loss of RTG cooling is covered in Paragraph 3.4.

- The design concept of the liquid fluorine oxidizer system on the F_2PU payload is a blowdown type where the internal pressure is maintained by internal cooling supplied by an external LN_2 supply. Venting or boiloff of the LF_2 tank is an emergency procedure only. However, a vent and fluorine disposal system must be provided at the pad in case of a fluorine-leak or overpressurization of the LF_2 tank.

If the backout contingency is initiated by a malfunction of the liquid fluorine oxidizer system, provisions for pressure relief, venting, and draining of the LF_2 system must be available at the pad. The design of the pad vent system and fluorine oxidizer system should allow gas and liquid to be drained. If the integrity of the fluorine oxidizer system is sound, draining at the pad is not recommended. This recommendation is based on the requirement that the loaded LF_2 tank pressure be maintained at a low pressure (small positive pressure) until released from the Orbiter in space. Processing and launch of a LF_2 tank near operating pressure (250-350 psi) should be avoided since this is in direct violation of Shuttle safety guidelines and exposes ground personnel and the Orbiter to a hazard with potential catastrophic effects.

The operations required to perform the general backout contingency for the IUS/F_2PU/PJP cargo are shown on Figure 26. This contingency is not initiated by a malfunction of the liquid fluorine oxidizer system. After Orbiter and IUS safing, the major concern for this contingency is maintaining the fluorine cooling, exposure to RTG radiation, and pyrotechnic devices. In the plan for this contingency, a portable LN_2 servicer cooling system is connected to the fluorine propulsion unit in the PCR.

If the handling of an LN_2 servicer in the PCR and in the canister or in conjunction with the canister appear too unwieldy, rather than connect the fluorine stage to an LN_2 servicer at the point shown in the alternative flow (within PCR), it may be possible to reconnect after the canister has been installed on the transporter. TRW estimates, based on a preliminary LF_2 tank configuration, that the tank pressure will remain within an acceptable value up to 6 hr after its cooling medium is disconnected.

3.3.1.1 Time Line

The time line and sequence of operations required to perform the backout contingency are shown in Figure 27. The time from initiating the backout contingency to arrival at SAEF #1 with the cargo is approximately 42 hr. Propellant dumping for the cargo and Orbiter are performed sequentially to reduce the possibility of a fire hazard from leakage of reactants. The pad is closed when the contingency is initiated.

3.3.1.2 Safing Requirements

The following summary of the constraints and safing requirements that must be performed during the backout contingency is:

- Drain and purge IUS N_2O_4 and lines.
- Drain and purge IUS and F_2PU hydrazine tank and lines.
- Vent IUS tank pressurizing systems.

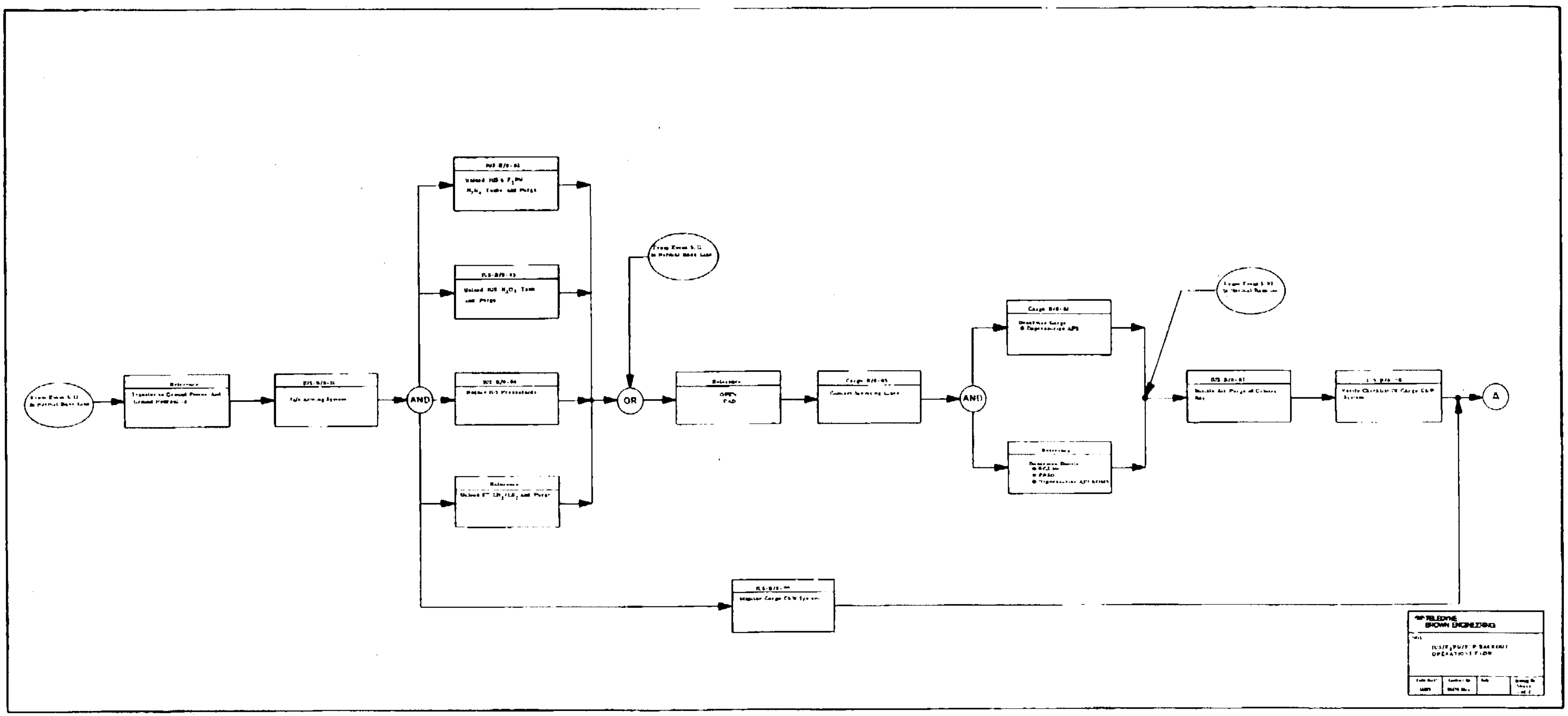


FIGURE 26. IUS/F_2PU/PJP BACKOUT OPERATIONS FLOW (SHEET 1 Of 2)

53-A

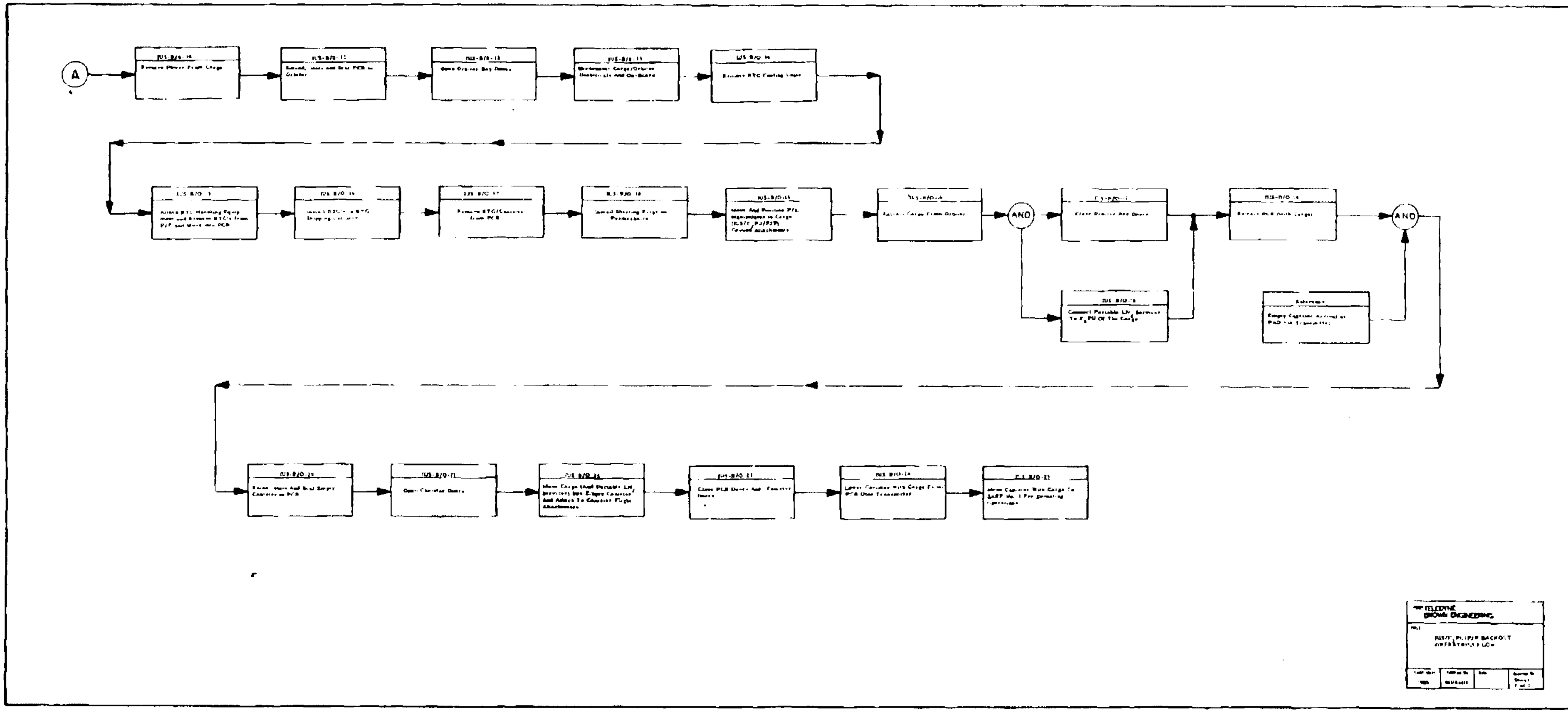


FIGURE 26. IUS/F_2PU/PJP BACKOUT OPERATIONS FLOW (SHEET 2 of 2)

54-A

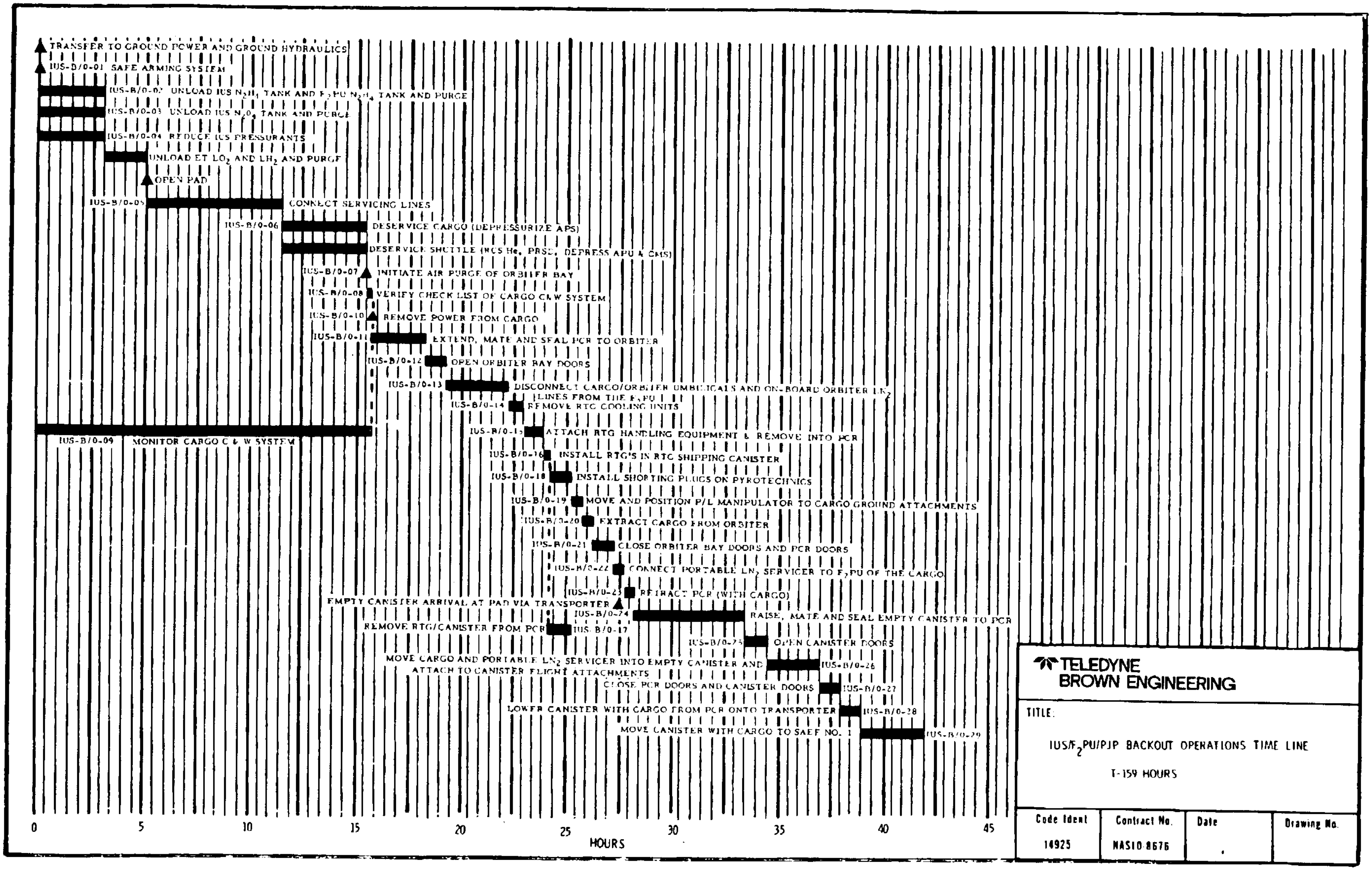


FIGURE 27. IUS/F_2PU/PJP BACKOUT OPERATIONS TIME LINE

- Unload ET LOX and LH_2 tanks and purge.
- Open pad.
- The payload N_2O_4 and N_2H_4 servicing units described in Volume 3 should provide for draining, purging, and drying of the propellant tanks and safe disposal of the propellant effluents.
- Connect payload service lines and vent F_2PU, PJP, and IUS APS pressurants.
- Before the doors are opened, the absence of hazardous/toxic gases should be verified. A hazardous gas analyzer system that would determine the presence of all gases is desirable.

After access to the cargo bay is attained via the PCR, two basic approaches are available. The first is to remove the cargo as quickly as possible, safe ordnance devices, and remove RTG's at SAEF #1. This requires RTG cooling during transport in addition to the fluorine cooling. The preferred approach, as shown in the contingency flow, is as follows:

- Disconnect and short Class A Explosives (EED's).
- Remove RTG's.
- Disconnect cargo umbilicals from the Orbiter.
- Remove payload.

This approach limits, as much as practical, the interaction of potential hazards and limits the number of personnel exposed to the various hazards.

3.3.2 Vertical Changeout at the Pad

This contingency plan is inherently complex because of the hazardous materials used in the payload comprising the cargo and is further complicated by the various options that were considered in dealing with the payload changeout combinations. Four options were developed as part of this contingency plan:

- Changeout of the PJP only.
- Changeout of the F_2PU/PJP.
- Changeout of the IUS/F_2PU/PJP cargo with the PCR capable of handling one cargo at a time.
- Changeout of the IUS/F_2PU/PJP cargo with the PCR capable of handling two cargoes at a time.

The operations required to perform these four contingency operations are shown in Figure 28. This figure shows the operations, common to all four options, required to safe the Shuttle and payload before access is gained to the payload bay through the payload changeout room, and the operations required for the four vertical changeout options.

3.3.2.1 Time Line

The time line and sequence of operations for the four changeout options are given below.

3.3.2.1.1 Changeout of PJP Only

This contingency operation requires that the RTG's be removed from the original PJP and installed on the new PJP unit. Also, the RTG's cooling system has to be removed prior to the changeout of the PJP's and reinstalled afterwards.

The time line and sequence of operations required to perform changeout of the PJP payload are shown in Figure 29. The time required from initiation of this contingency to return to normal operations at Shuttle and payload propellants loading is approximately 36 hr.

3.3.2.1.2 Changeout of F_2PU and PJP

In this option, the F_2PU/PJP assembly would be changed out for an identical unit. In addition to the RTG's cooling problem discussed in the first option, an even more critical problem is associated with the cooling requirements for the F_2PU.

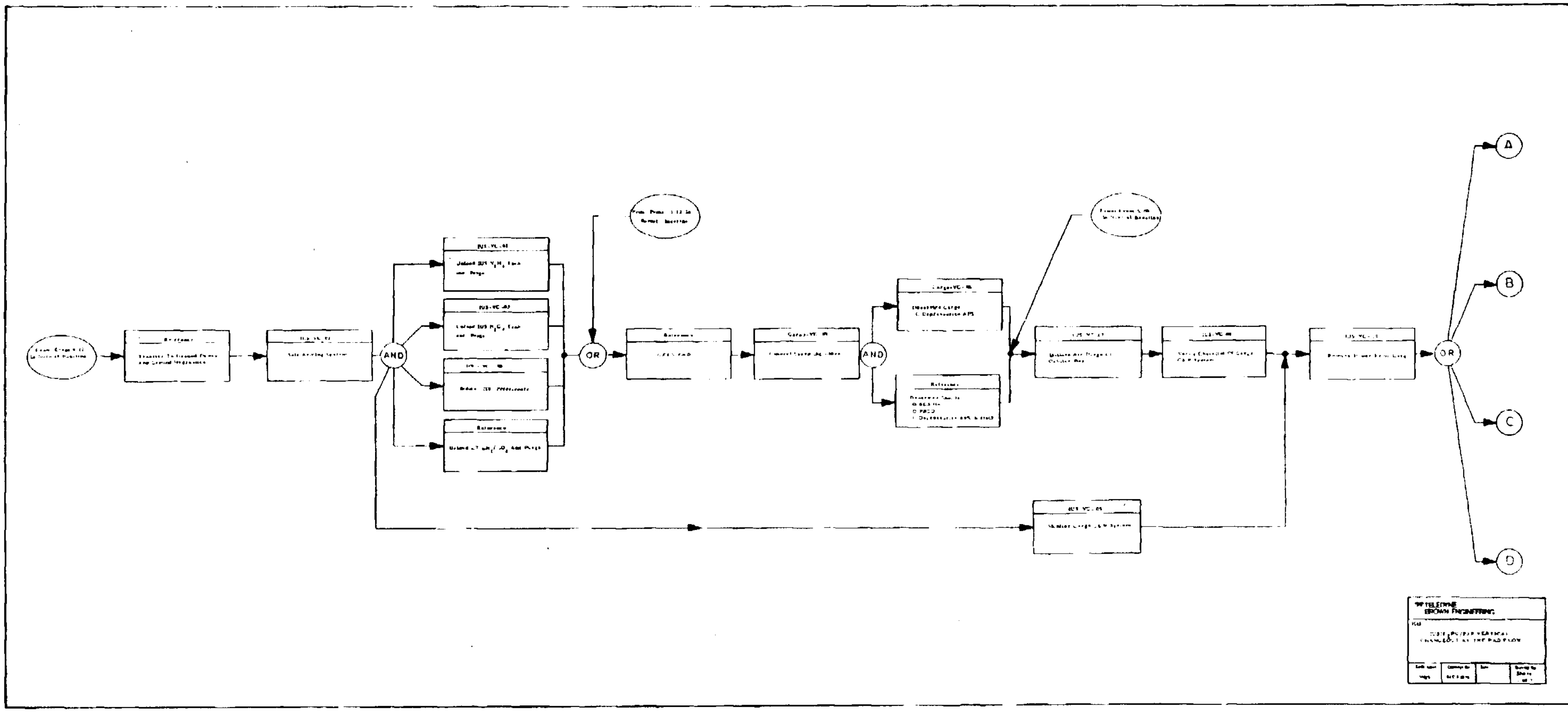


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 1 of 7)

58 - A

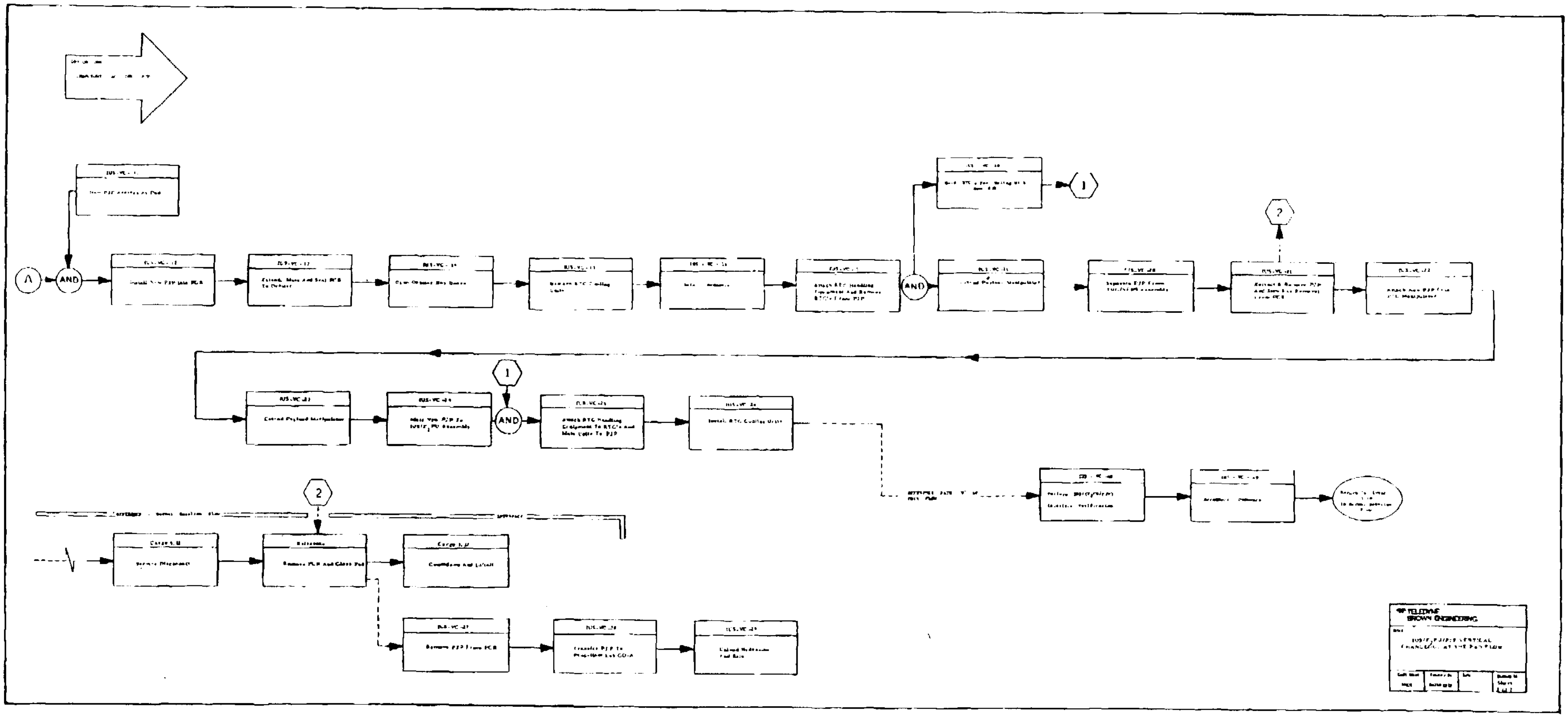


FIGURE 28. IUS/F$_2$ PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 2 of 7)

59 - A

59 - B

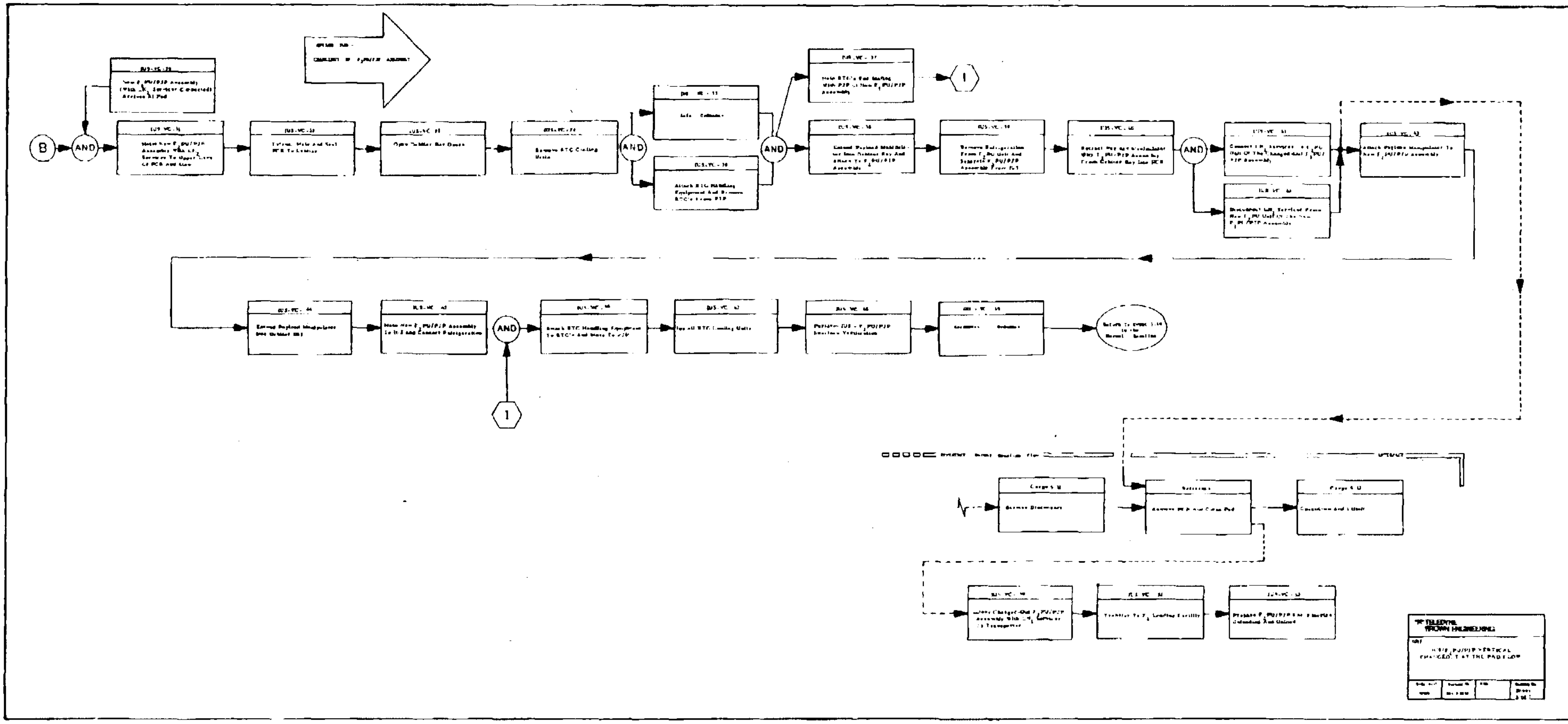


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 3 of 7)

60 - A

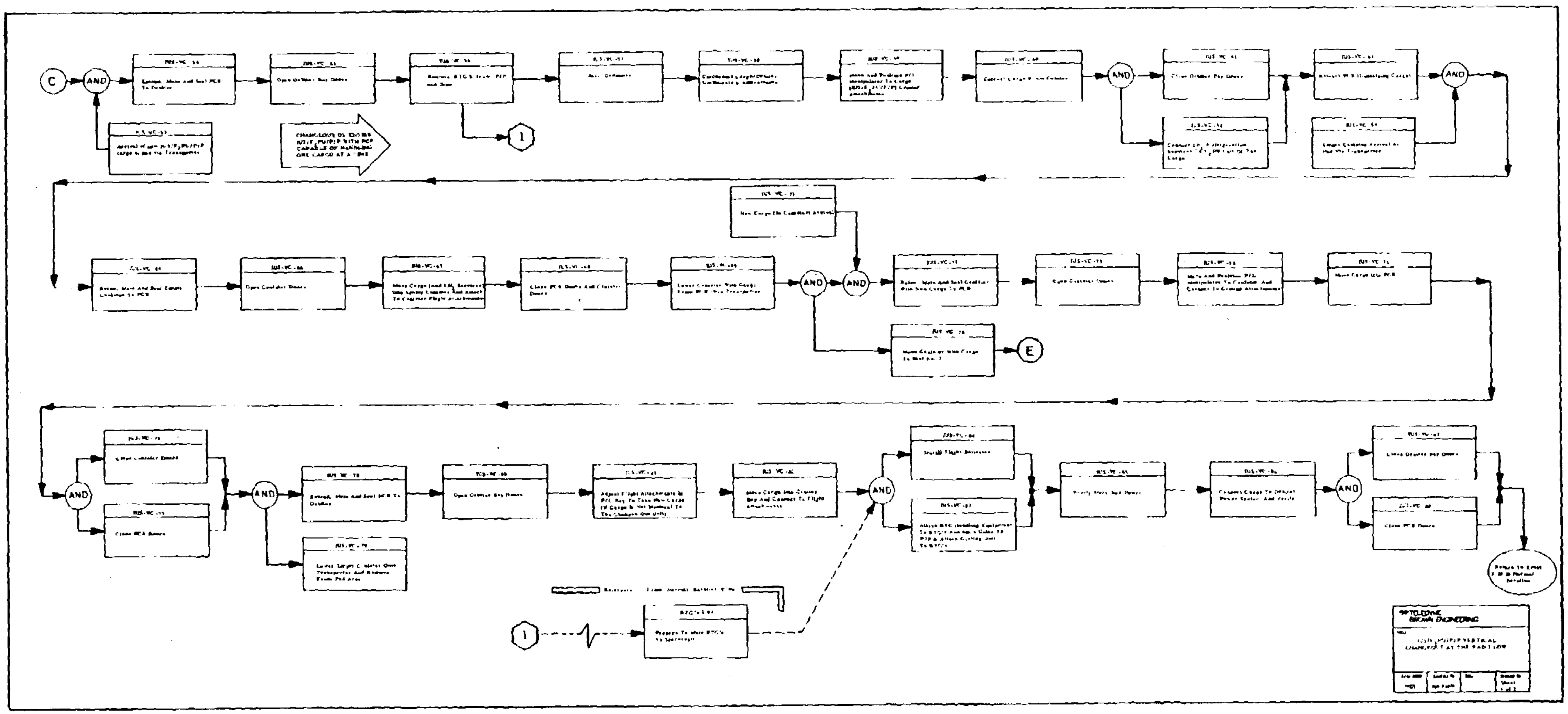


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 4 of 7)

61 - A

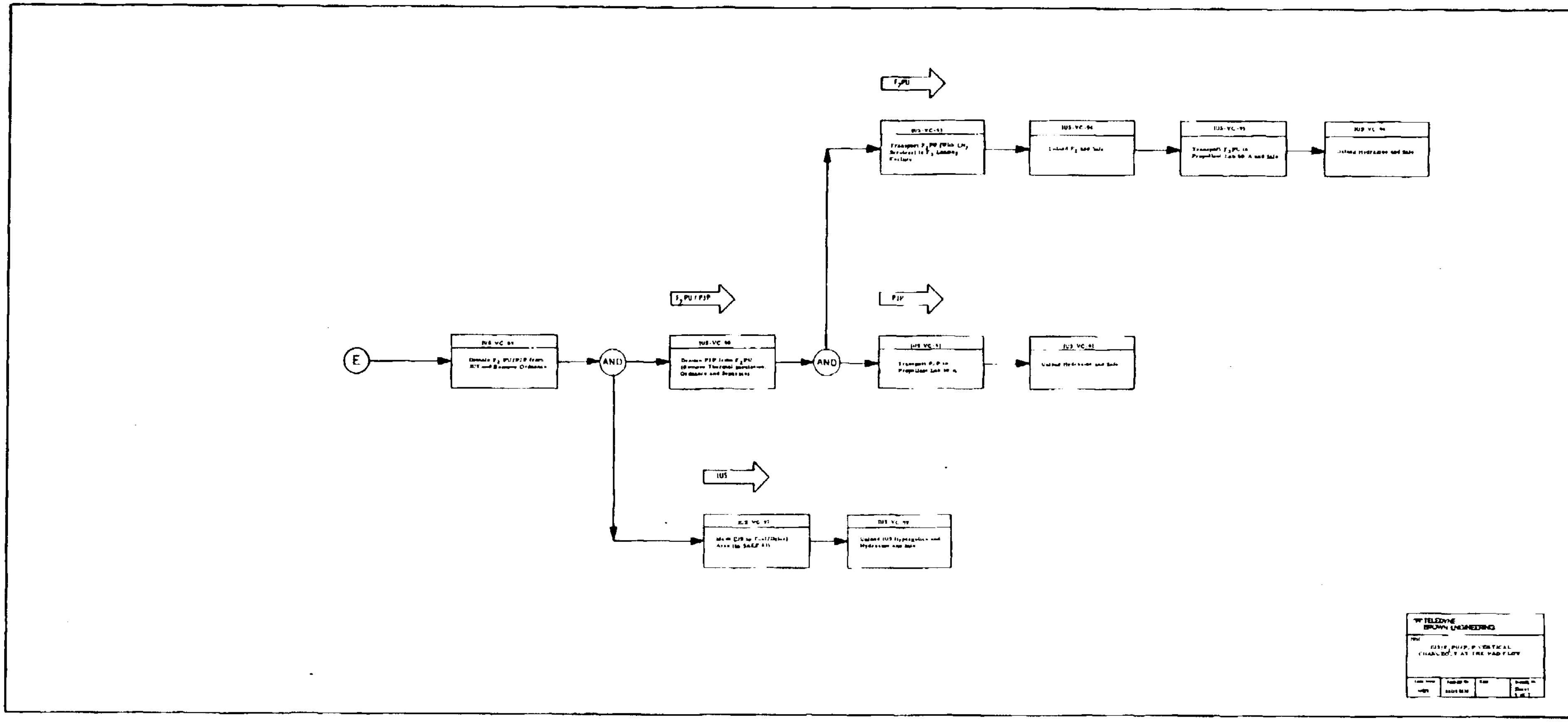


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 5 of 7)

62-A

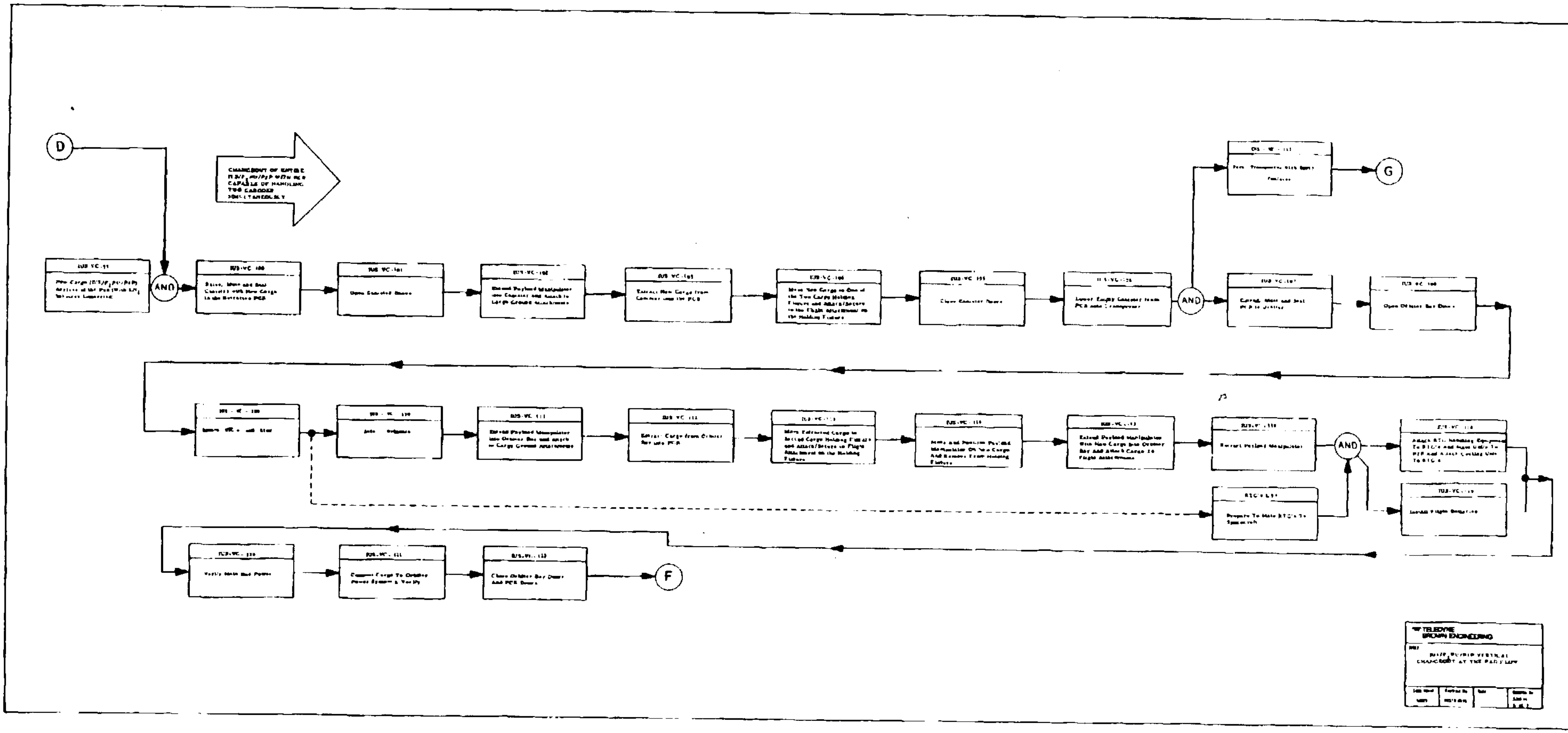


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 6 of 7)

63 - A

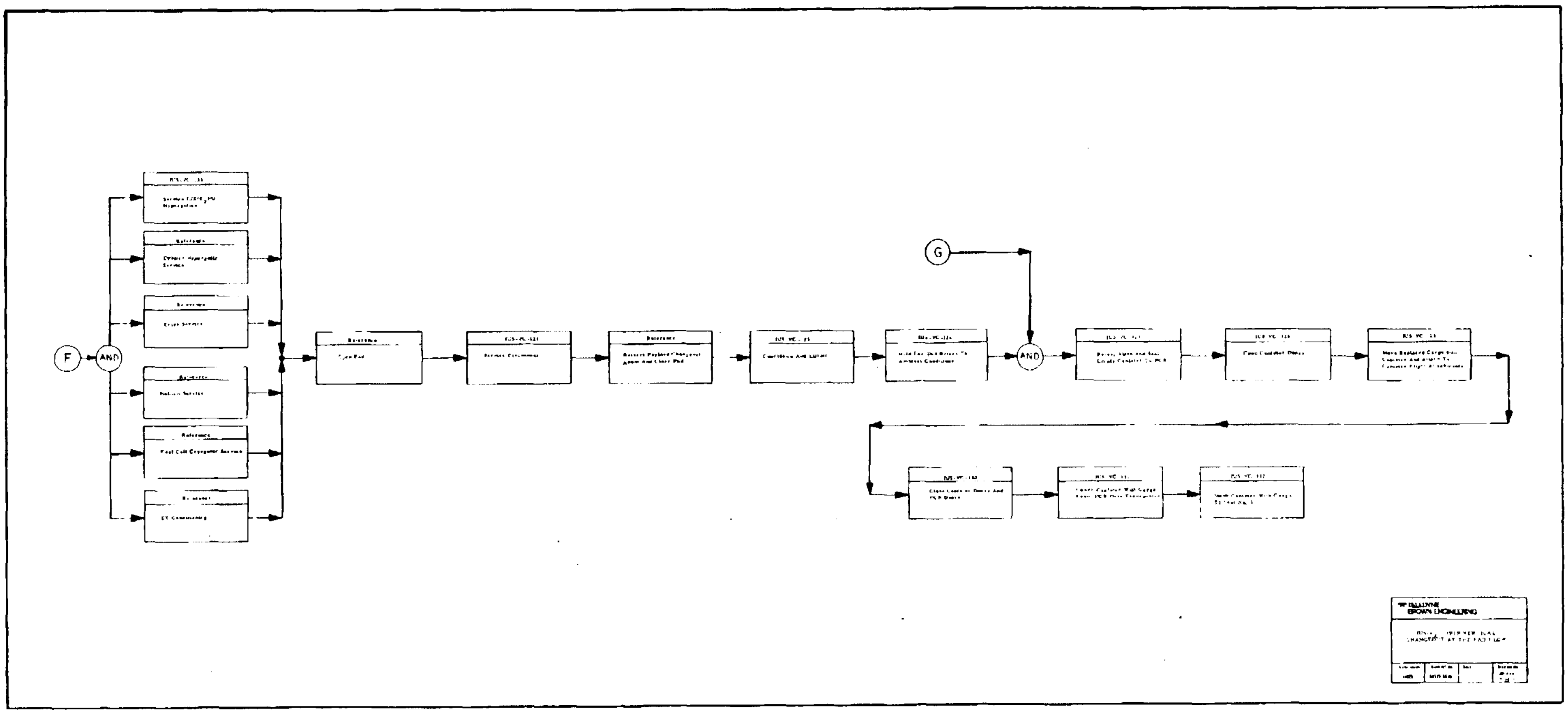


FIGURE 28. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD FLOW (SHEET 7 of 7)

64-A

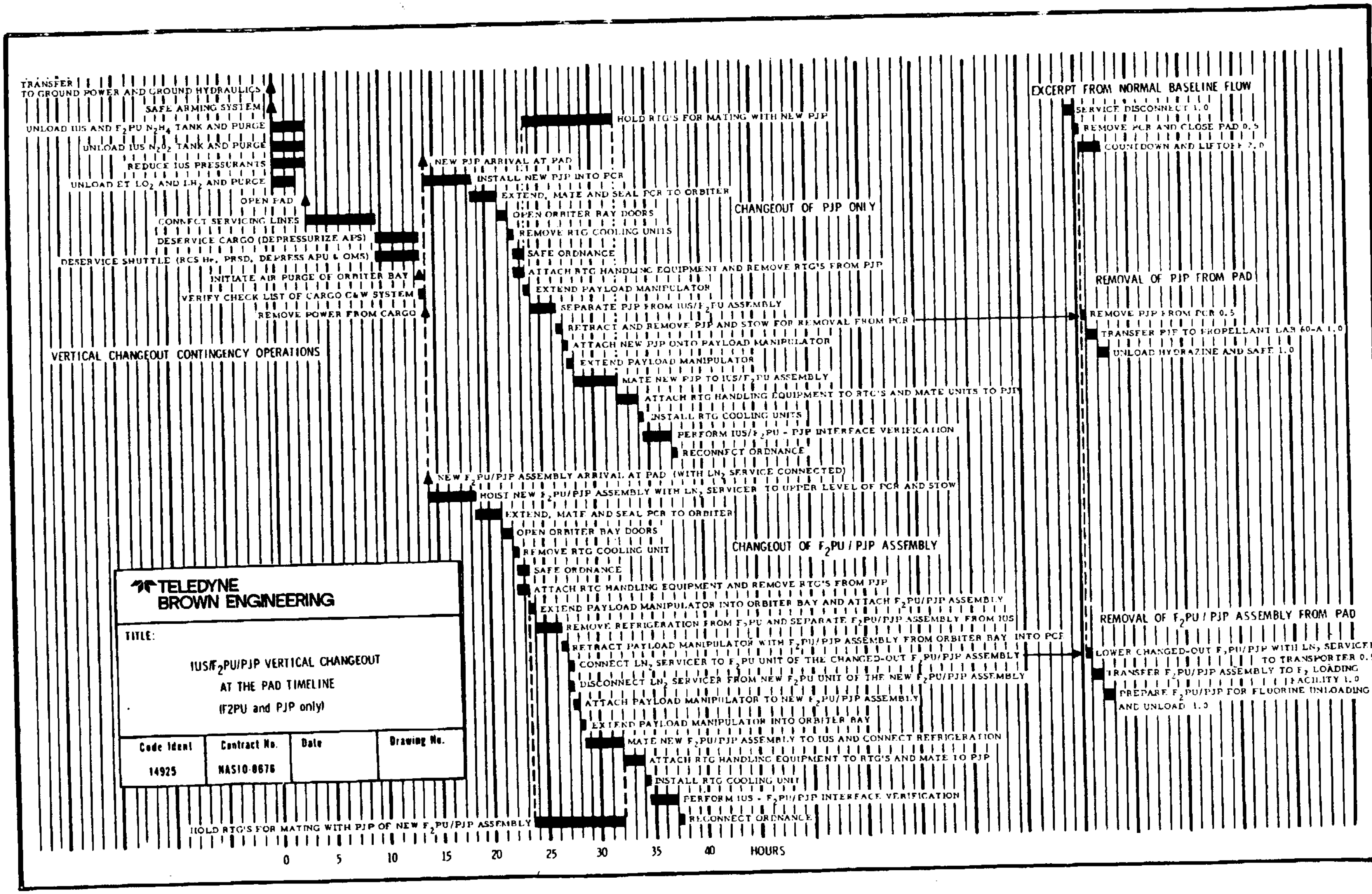


FIGURE 29. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD TIME LINE (F_2PU AND PJP ONLY)

65-A

This unit requires a special LN_2 servicer to accompany the fluorine stage throughout the operations until it is connected to the cargo's fluorine refrigeration system. The mobile LN_2 servicer is then connected to the fluorine stage of the F_2PU/PJP that was just changed out, prior to its transfer back to the F_2 loading facility for safing and deservicing. The time line and sequence of operations required to perform this changeout are shown in Figure 29. The time required from initiation of this contingency to return to normal operations at Shuttle and payload propellants loading is approximately 36 hr.

3.3.2.1.3 Changeout of the Entire IUS/F_2PU/PJP with One Cargo at a Time in the PCR

In this option, the assumption is made that an entire cargo of identical composition will be exchanged for the original. It is further assumed that the RTG's will be taken off the first cargo and installed on the new. As in the previous option, RTG's cooling and the fluorine stage cooling are the big problems. The time line and sequence of operations required to perform this changeout are shown in Figure 30. The time from initiation of the contingency operation to launch of a new cargo is approximately 73 hr.

3.3.2.1.4 Changeout of the Entire IUS/F_2PU/PJP with the PCR Capable of Handling Two Cargoes

In the final option to this contingency, the same assumptions were made as in option three, with the additional requirement that the PCR accommodate two cargoes at the same time. This option requires only one extension and retraction of the PCR, whereas in option three two extensions and retractions were required. The largest impact will be on the design of the PCR. It will require two cargo holding structures to be added to the PCR and possibly a more capable payload manipulator with added degrees of freedom. From a hazard point of view, the fluorine, hydrazine, and other hazardous materials concentrations will be compounded by having two cargoes in the PCR simultaneously. Also, the original cargo that was removed from the Orbiter will have to remain in the PCR throughout launch or a holdup of four additional hours will be required to remove the original cargo from the PCR and pad area prior to launch. The time line and sequence of operations required to perform this contingency operation are shown in Figure 31. The time from initiation of the contingency operation to launch of a new cargo is approximately 64 hr.

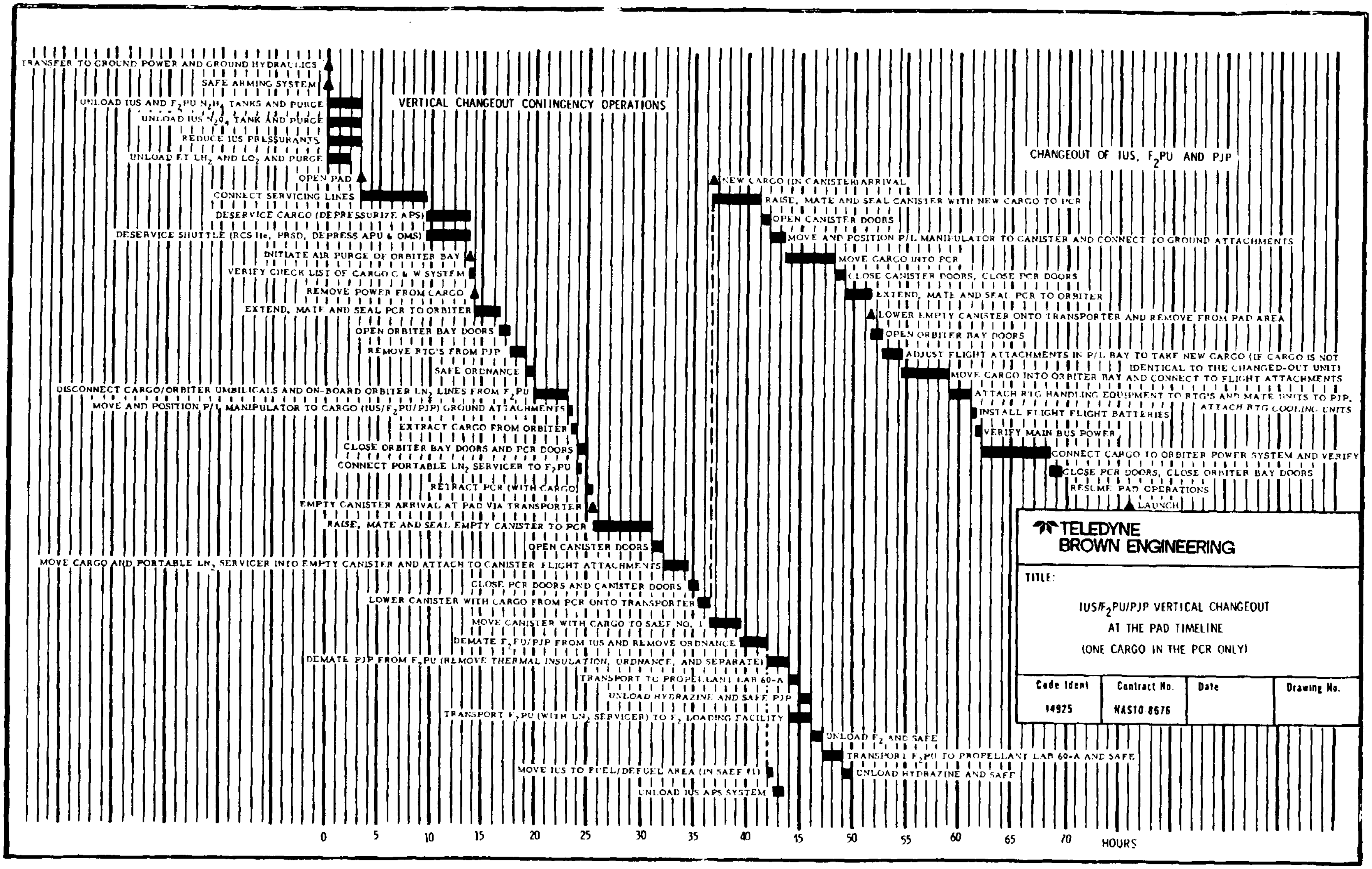


FIGURE 30. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD TIME LINE
(ONE CARGO IN THE PCR)

67-A

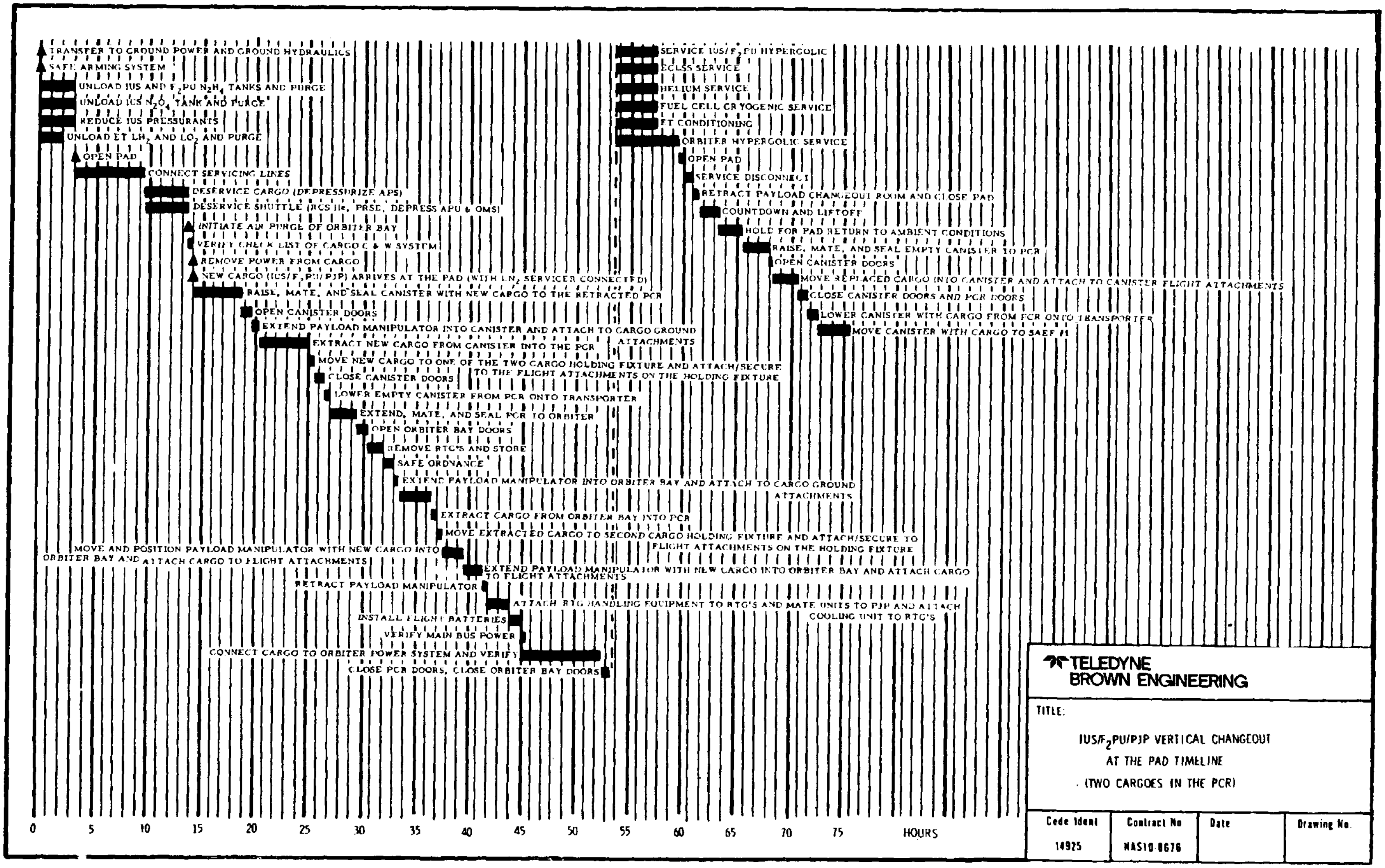


FIGURE 31. IUS/F_2PU/PJP VERTICAL CHANGEOUT AT THE PAD TIME LINE
(TWO CARGOES IN THE PCR)

68-A

3.3.2.2 Safing Requirements

The safing requirements for vertical changeout of the IUS/F_2PU/PJP are similar to those for backout operations discussed in Paragraph 3.3.1. The major steps in the preferred sequence are:

- Remotely safe Shuttle and payload by draining propellants and venting pressures (except for LF_2).
- Verify no toxic/hazardous gases present in the cargo bay before entering.
- Safe all ordnance (with shorting plugs).
- Remove RTG's.
- Remove cargo/payloads.

3.3.3 Mission Abort

In this contingency our primary concern is with the cargo and its safing. Since the abort can take place at various points in the mission, cargo related safing must be examined for the worst case. Abort situations of concern are the inability to deploy the cargo (payload bay doors will not open or cargo will not deploy or separate) and failure to attain orbit. The worst case abort for any cargo based on time available for safing is abort at SRB separation. However, for this mission abort from orbit is of concern because this cargo carries onboard a limited supply of cooling water for the PJP RTG's and a limited supply of LN_2 for the fluorinated oxidizer system.

The operational flow for the in-flight safing activities for the cargo are shown in Figure 32.

3.3.3.1 Time Line

The mission abort contingency flow through landing is shown in Figure 33.

3.3.3.2 Safing Requirements

The following recommended safing requirements for in-flight mission abort of this cargo are:

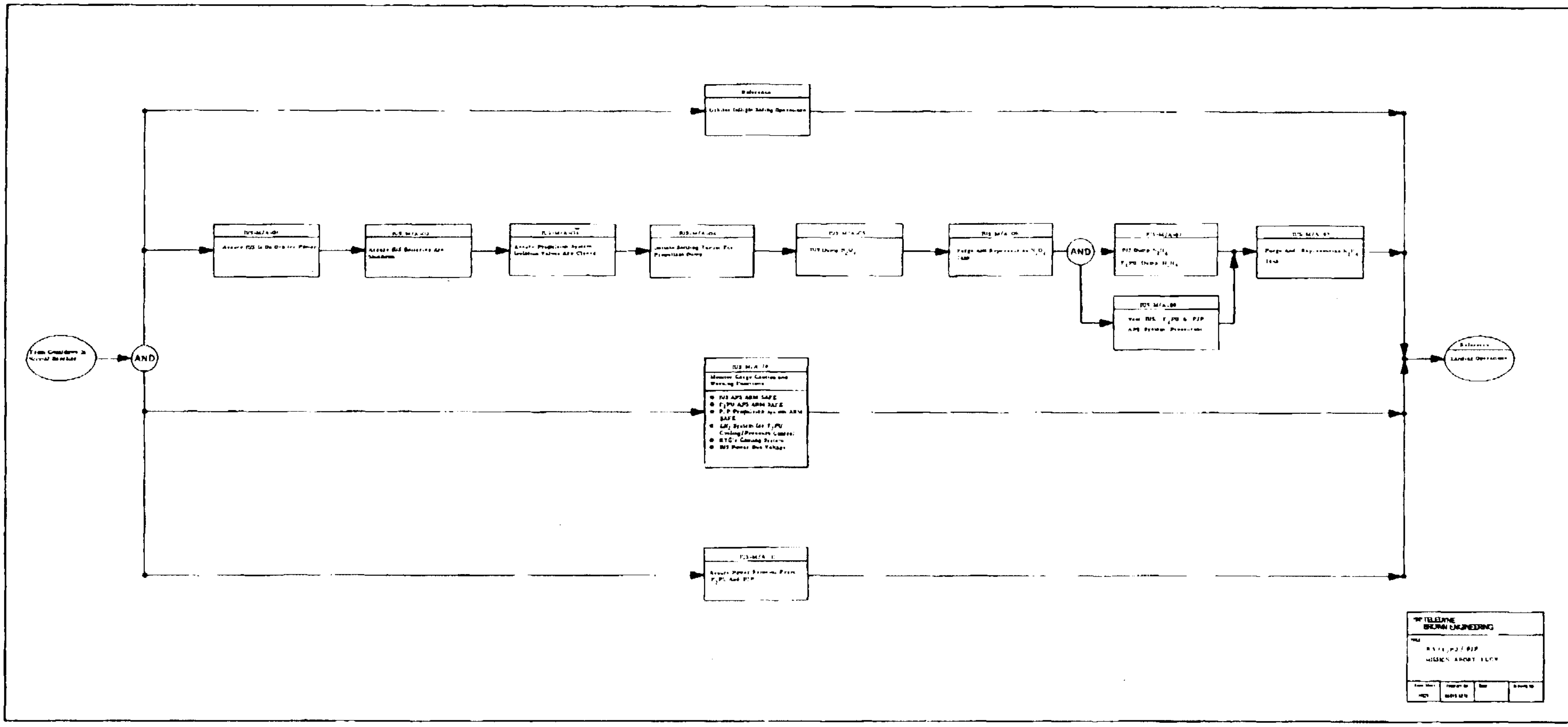


FIGURE 32. IUS/F_2PU/PJP MISSION ABORT FLOW

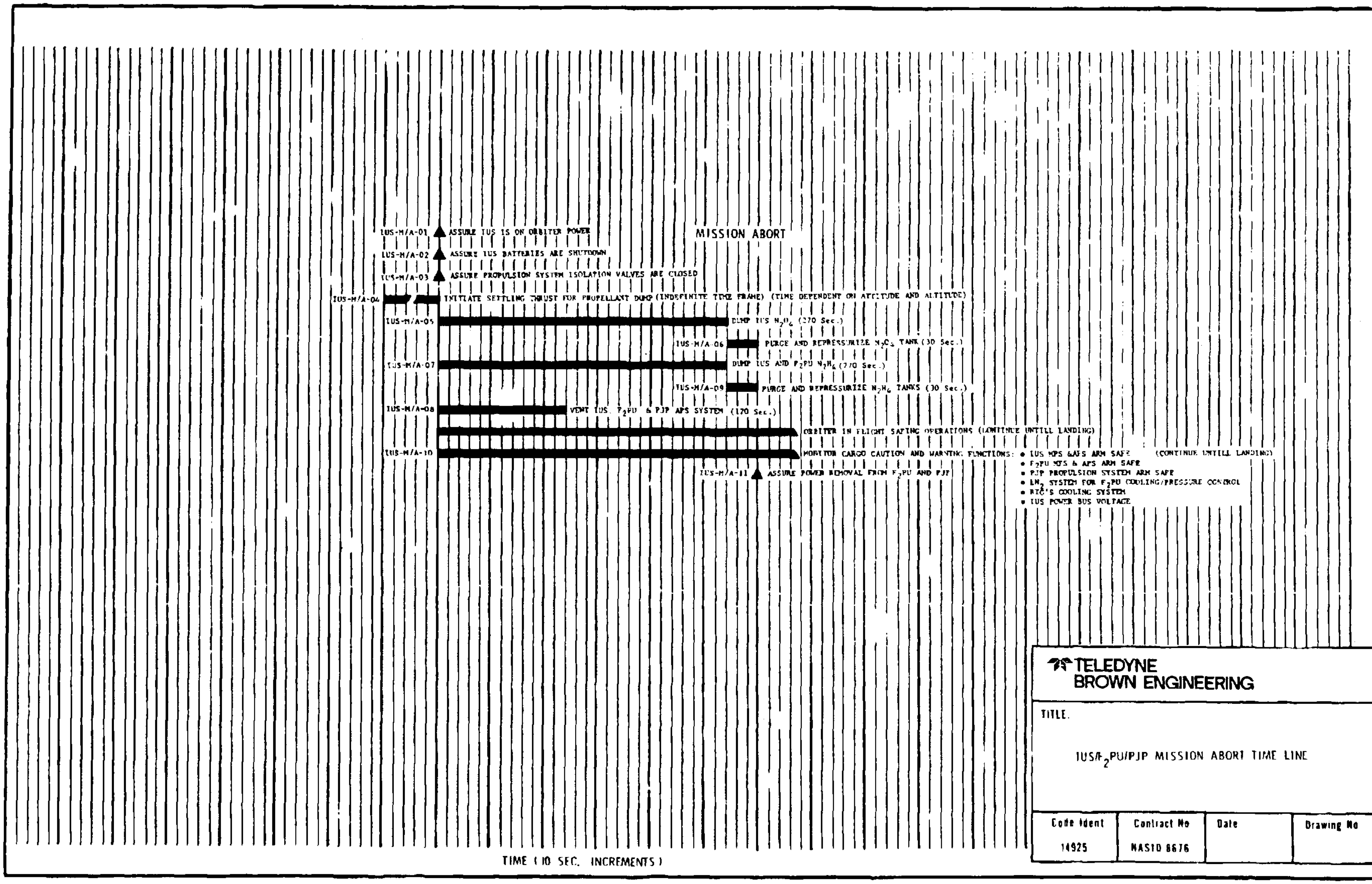


FIGURE 33. IUS/F_2PU/PJP MISSION ABORT TIME LINE

- Dump out IUS N_2O_4 and N_2H_4 through the Orbiter vent system and repressurize the tanks to a positive pressure for landing.

- Dump F_2PU MPS hydrazine through the Orbiter vent system and repressurize the tank to a positive pressure for landing.

- Vent IUS, F_2PU, and PJP APU pressurants overboard through the Orbiter vent system.

- Monitor payload caution and warning parameters.

The requirements for dumping of the LF_2 tank in-flight are being considered in other NASA studies. Even though the fluorine stage probably presents the largest hazard upon landing, no overboard fluorine dumping was shown in the mission abort plan because fluorine is highly reactive and a special fluorine dump system would be required; the environmental impact of such an action has not been assessed; and as long as the fluorine system is stabilized and controlled, the hazards may be less in this state than in the dump mode. However, fluorine dump provisions should be provided for in-flight venting in the event that the fluorine system becomes uncontrollable.

3.3.3.3 IUS/F_2PU/PJP Contingency Special Support Equipment

3.3.3.3.1 RTG Cooling

The nominal post-landing Orbiter time line shows that 19 hr is required from landing until access is gained to the payload in the OPF. With only 15 hr of water supply onboard this cargo for cooling the RTG's, provisions must be made at the landing site for RTG cooling. It is recommended that this requirement be fulfilled with a mobile water cooling servicer since an abort landing may require additional time at the landing site.

3.3.3.3.2 Fluorine Oxidizer Tank Cooling

An abort landing of the IUS/F_2PU/PJP cargo requires that special consideration be given to the fluorine oxidizer whether in-flight dumping is performed or the LF_2 tank is returned intact. Because there are presently no provisions for handling fluorine in the OPF, the following options are available:

a. Provide onboard LN_2 cooling supply or portable LN_2 dewar at the landing site to maintain tank thermal/pressure balance until the F_2PU can be removed from the Orbiter, demated, and transported to the fluorine facility. This would require, under normal operations, a minimum of 19 hr and exposes the Orbiter, OPF facility, and operating personnel to the fluorine hazard. Contingency operations resulting in an abort landing could require additional time.

b. Vent and dispose of the fluorine at the landing strip. This action requires a portable fluorine disposal unit (charcoal burner), portable vent lines for connecting the Orbiter fluorine vent to the fluorine disposal unit, a heated GN_2 mobile servicer to be connected to the LF_2 tank ground cooling umbilical to boil off the LF_2, and a GN_2 supply to purge the LF_2 tank. Previous studies report that boiloff time for similar fluorine upper stage concepts using the heated GN_2 method would require approximately 6 hr.

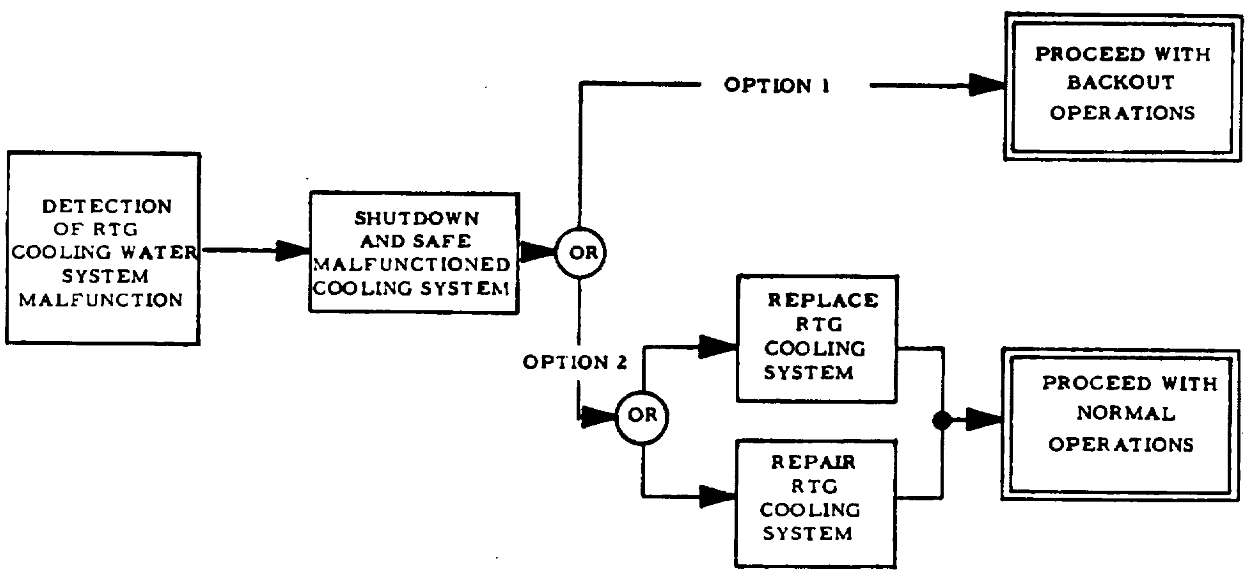
The final recommendation as to the handling of the fluorine oxidizer in the event of an intact abort depends largely on whether in-flight dumping is required or allowed. The effects on the environment and ecology of dumping fluorine into near space should be studied. Dumping in-flight would reduce the time required at the landing strip to vent residual LF_2 and allow the post landing operations to proceed without the 6-hr delay required by option b. Another possible design impact resulting from an abort with a fluorinated oxidizer system is that provisions must be made for such an emergency to be able to drain in the horizontal position.

3.4 ACCIDENT CONTINGENCY--LOSS OF RTG COOLING FOR THE PJP ON THE IUS/F_2PU/PJP CARGO

This is an accident-type contingency situation where the undesired event is loss of RTG cooling after installation in the payload bay. The normal processing flow developed for this cargo (Volume 3) established RTG installation at the pad at 14 hr before lift-off. The RTG's are cooled by a ground water supply through the T-0 umbilical until just before lift-off when the onboard supply is activited. The onboard cooling water supply has tentatively been established for 15 hr of cooling.

3.4.1 Contingency Remedial Options

Upon detection of the RTG cooling water system malfunction on the ground, two basic options are available. In the first option, the malfunctioned cooling system must be shut down and safed followed by backout operations. The second option also requires that the cooling system be shut down and safed. If the decision is to proceed with normal operations rather than backout, then either the entire RTG cooling unit can be replaced or if less time is required, the unit could be repaired. These options are shown in the following diagram:



The effect of the RTG's loss of cooling is overheating in the Orbiter bay. Probably the highest potential impacts are on the RTG unit and the fluorine stage, with the possible release of radiation and loss of control of the delicate fluorine heat/pressure balance. The worst case condition for this failure would require approximately 18 hr. of Shuttle and cargo safing from initiation of a contingency until access to the payload bay is attained via the PCR (Figure 27).

3.4.2 RTG Cooling System Definition

To establish the fundamental safing operations for this contingency, a likely candidate cooling system for the RTG's was devised. The basic requirements for this system are shown in Figure 34. Such a system must have, as a minimum, the following:

- On-pad water supply
- Pump
- RTG cooling water jackets
- Overboard dump valve
- Water boiler and heat exchanger
- RTG jacket water valve
- Boiler feed valve
- Water storage tank onboard Orbiter
- Pressure and temperature sensors in water cooling loop

3.4.3 Contingency Failure Modes and Effects

This contingency can be brought into effect during ground operations by any one of the following:

- Loss of on-pad water supply
- Rupture of RTG cooling jackets, lines, or fittings
- Overboard dump valve fails to water boiler position.

Except for rupture of the RTG cooling water jackets or lines, a transfer to the onboard supply would provide cooling until the backout contingency through removal of RTG's could be completed.

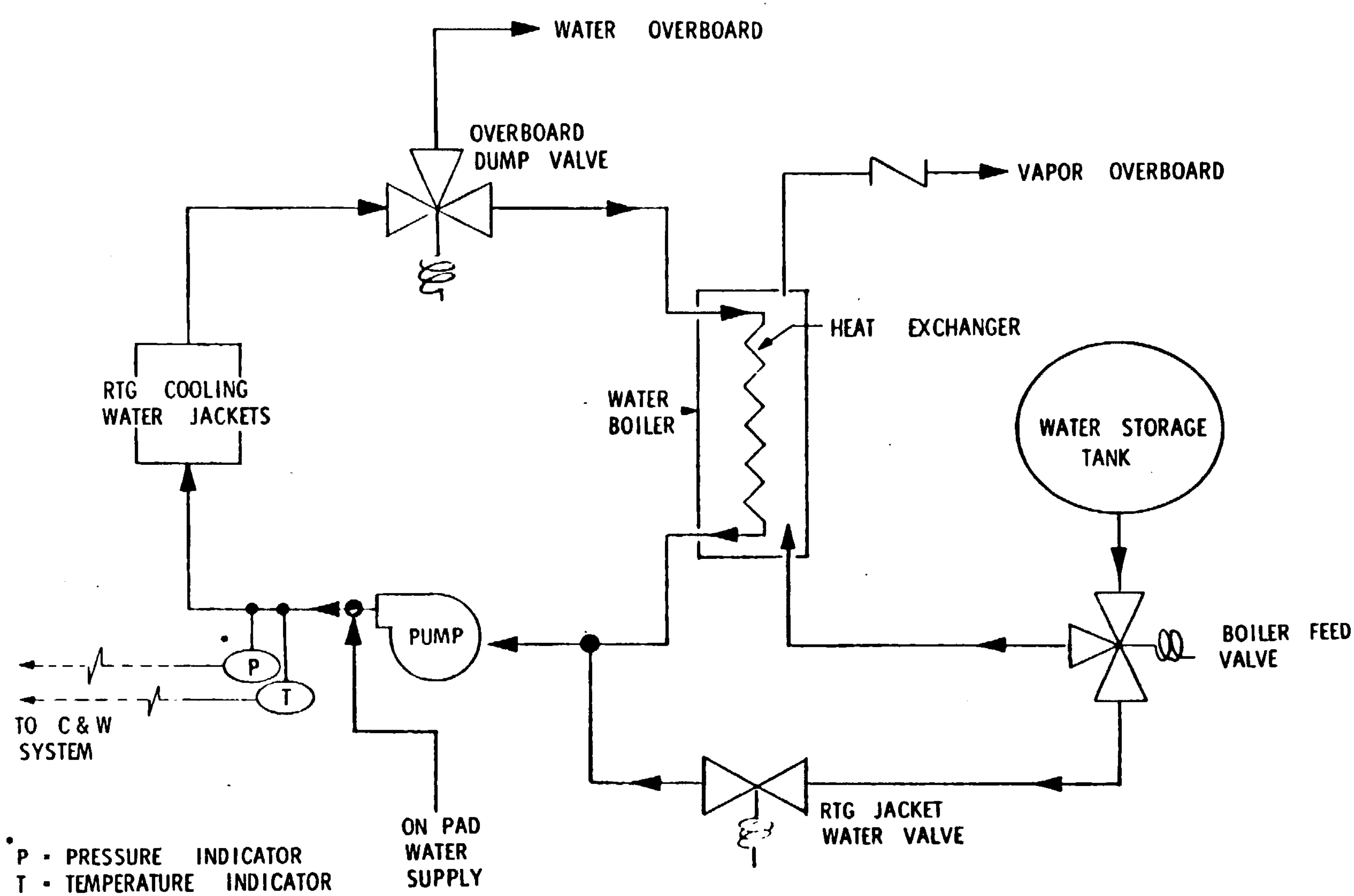


FIGURE 34. RTG WATER COOLING SYSTEM

After transfer to the onboard cooling supply, this contingency can be brought into effect by any one of the following failures:

- Rupture or leakage of RTG cooling water jackets or lines
- Pump failure
- Boiler rupture or leakage
- Rupture of heat exchanger
- Failure of overboard dump valve to open to dump or to boiler
- Failure of boiler feed valve to open to boiler or to cooling loop
- Rupture or leakage of water storage tank
- Failure of RTG jacket water valve to open when required
- Malfunctioning or false reading of pressure and/or temperature indicators to the C&W system.

With the exception of failure of the overboard dump valve and rupture or leakage of RTG cooling water jackets and lines, a transfer back to the on pad water supply can provide cooling until the backout contingency allows removal or repair of the RTG cooling systems. As a minimum, the following redundancy provisions should be included in the cooling system design:

- Pipe on-pad water supply to the RTG jackets independent of the on-board supply.
- Provide redundant overboard dump valve

Also, the integrity of the RTG coolant jackets and system should be verified by a pressure/leak test prior to installation of the RTG's.

3.4.4 Fault Isolation--Loss of RTG Cooling

The contingency action required depends upon which failure/malfunction occurs. Several of the component malfunctions will require the same actions. The detection of this contingency type requires a temperature measurement either on the RTG case, in the cooling loop or both. Therefore, heat sensors, monitorable through the C&W system, are required. If an overheating condition is detected but with no pressure loss in the cooling loop, then the probable source of trouble is with a leak or rupture of the water boiler or storage tank. Since it would require an elaborate monitoring and control system to fault isolate every major component in the cooling system, a more practical solution is to make some worst case assumptions as to the faulty items and proceed with the shutdown and safing of the cooling water system. If there is a rupture of the boiler, the action required is to shut off water from entering the boiler. Because there is no way to drain, or more rapidly deplete it, the boiler must be allowed to exhaust itself as vapor and through leakage until empty. If there is a leak or rupture of the water storage tank, the procedure would be to deplete the tank, by way of the overboard dump, as rapidly as possible to minimize water leakages on the cargo and in the Orbiter bay. If the pressure indicator within the cooling loop has indicated a pressure loss, the malfunction is either a pump failure, or a rupture of the cooling water jackets or heat exchanger, which would require a shutoff of water to and draining of water from the cooling loop.

3.4.5 Contingency Flow Plan

After the remote operations on the RTG cooling water system have been completed, basic backout operations are initiated. When the Orbiter bay doors have been opened, the RTG cooling water system can be inspected and a decision made as to whether to continue the backout operations or to repair/replace and proceed with the normal processing. The operational requirements for this contingency are shown in Figures 35 and 36.

3.5 SPECIAL SUPPORT EQUIPMENT

Special support equipment is unique equipment recognized as essential for the successful application of the contingency plans. These items have not been previously called for in the normal processing plans and thus are peculiar to their respective contingency situations.

For each cargo, a listing of special support equipment for each contingency plan is provided. Sixteen items of support equipment

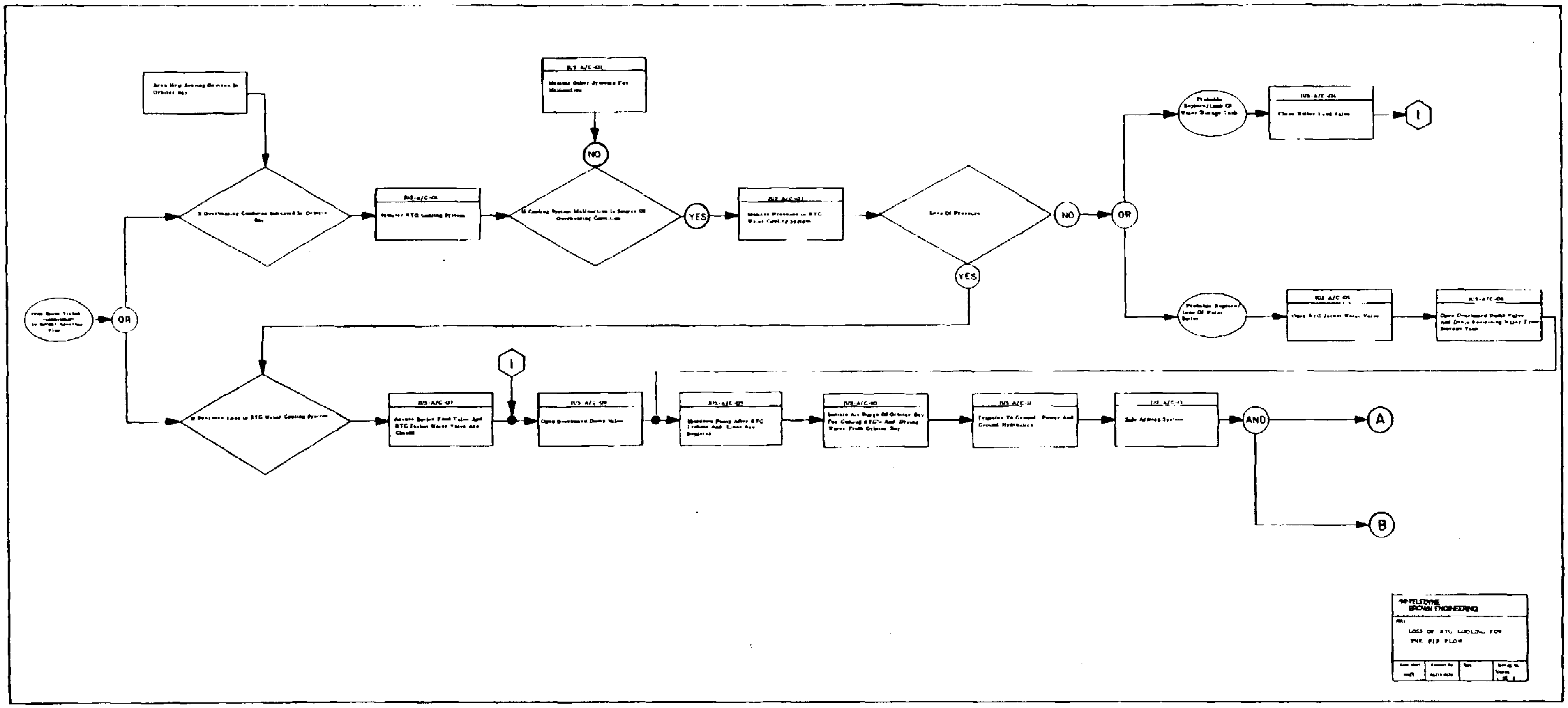


FIGURE 35. LOSS OF RTG COOLING FOR THE PJP FLOW (SHEET 1 of 2)

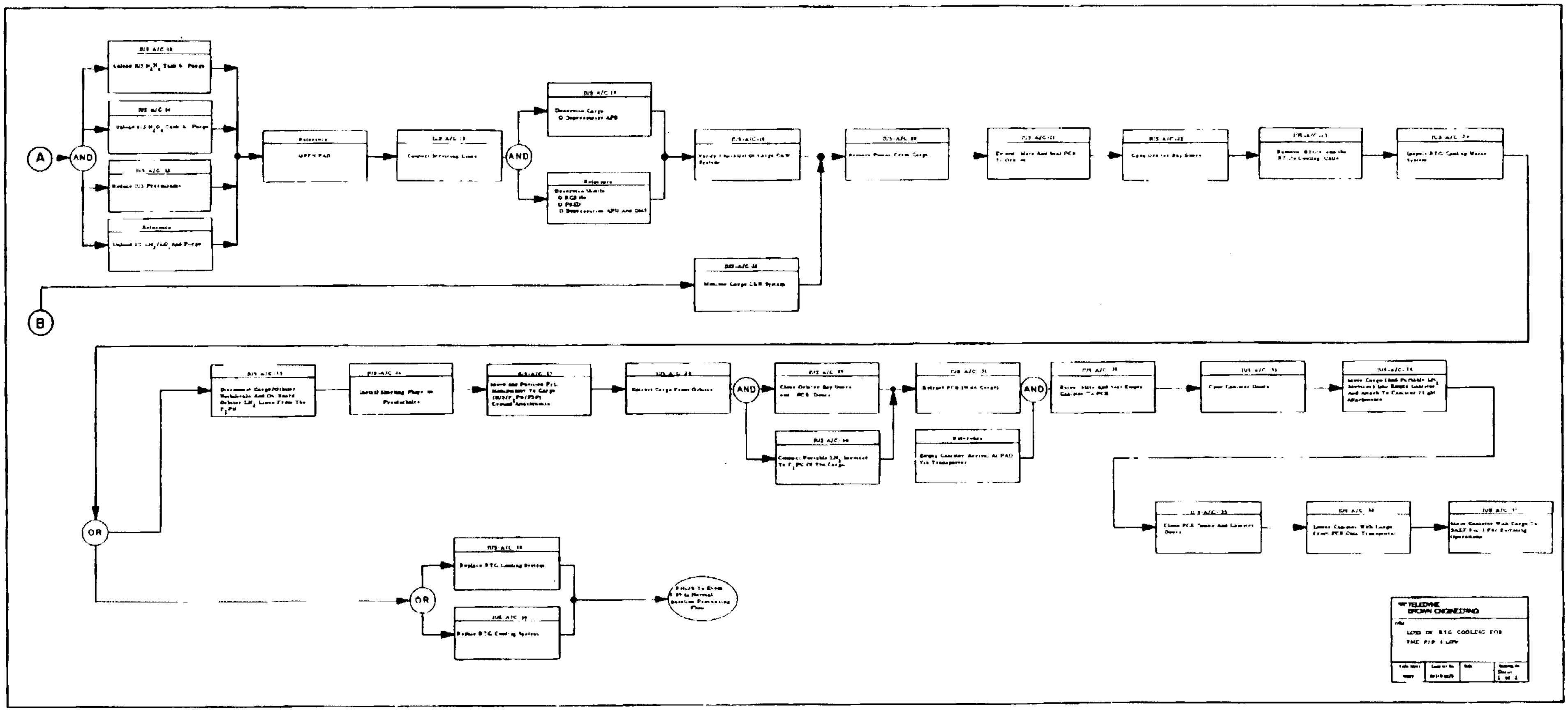


FIGURE 35. LOSS OF RTG COOLING FOR THE PJP FLOW (SHEET 2 of 2)

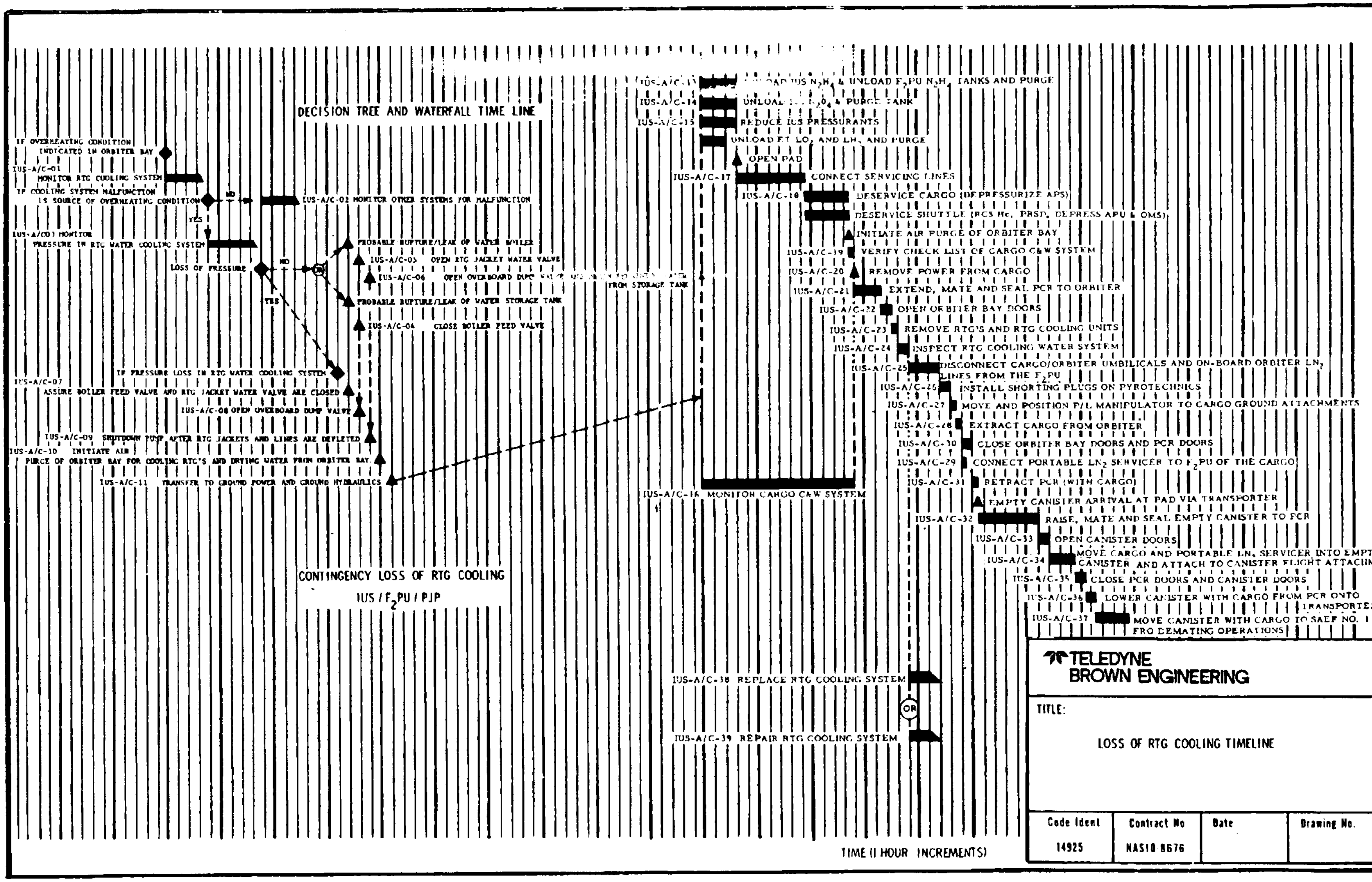


FIGURE 36. LOSS OF RTG COOLING TIME LINE

or facility modifications have been recognized as a result of the contingency plans. The essential requirements for each item are provided on the Support Equipment Identification sheets. The title, basic function, and description of each item are shown on the sheets designated C-1 through C-16.

SPECIAL SUPPORT EQUIPMENT PER CONTINGENCY PLAN

CARGO IDENTIFICATION SPACELAB/ATL

CONTINGENCY PLAN	SPECIAL SUPPORT EQUIPMENT
1. Vertical Changeout At The PAD	C-1 Orbiter Bay Vertical Access Mechanism and Work Platform
2. Ba[illegible]out Operations	C-1 Orbiter Bay Vertical Access Mechanism and Work Platform
3. Mis[illegible]on Abort	NONE
4. Normal Landing At Contingency Site	C-2 Interior Access Assembly C-3 Mobile Power Generator C-4 Portable Orbiter Hoisting Device C-5 Orbiter Strongback C-6 Piggyback Carrier Aircraft
5. Crash/Shock Condition Landing At KSC	C-2 Interior Access Assembly C-3 Mobile Power Generator
6. Crash/Shock Condition Landing At Contingency Site	C-3 Mobile Power Generator C-4 Portable Orbiter Hoisting Device C-5 Orbiter Strongback C-6 Piggyback Carrier Aircraft

SPECIAL SUPPORT EQUIPMENT PER CONTINGENCY PLAN	
CARGO IDENTIFICATION TUG/SEPS/SEOS	
CONTINGENCY PLAN	**SPECIAL SUPPORT EQUIPMENT**
1. Vertical Changeout At The PAD	C-1 Orbiter Bay Vertical Access Mechanism and Work Platform
2. Backout Operations	C-1 Orbiter Bay Vertical Access Mechanism and Work Platform
3. Mission Abort	NONE
4. Normal Landing At Contingency Site	C-3 Mobile Power Generator C-4 Portable Orbiter Hoisting Device C-5 Orbiter Strongback C-6 Piggyback Carrier Aircraft
5. Crash/Shock Condition Landing At KSC	C-3 Mobile Power Generator
6. Crash/Shock Condition Landing At Contingency Site	C-3 Mobile Power Generator C-4 Portable Orbiter Hoisting Device C-5 Orbiter Strongback C-6 Piggyback Carrier Aircraft

SPECIAL SUPPORT EQUIPMENT PER CONTINGENCY PLAN	
CARGO IDENTIFICATION IUS/F_2PU/PJP	
CONTINGENCY PLAN	**SPECIAL SUPPORT EQUIPMENT**
1. Vertical Changeout At The PAD	C-1 Orbiter Bay Vert. Access Mech. C-7 RTG Handling Ring C-8 RTG Handling Ring Sling C-9 RTG Support Yoke C-10 RTG Handling Dolly C-11 RTG Handling Rod C-12 PCR Cargo Handling Fixtures C-13 Modified Payload Manipulator
2. Backo[illegible] Operations	C-1 Orbiter Bay Vert. Access Mech. C-7 RTG Handling Ring C-8 RTG Handling Ring Sling C-9 RTG Support York C-10 RTG Handling Dolly C-11 RTG Handling Rod C-12 PCR Cargo Handling Fixtures C-13 Modified Payload Manipulator
3. Mission Abort	C-14 Mobile H_2O Cooling Unit C-15 Hot GN_2 Servicer C-16 Portable LN_2 Supply and Transfer Kit F-1-25 Fluorine Vent System
4. Accident Contingency - Loss of RTG's Cooling	SAME AS ITEM 2.

SUPPORT EQUIPMENT LISTING

UNIT/CATEGORY	LIST NUMBER
Special Support Equipment Required For Contingency Planning	C

SUPPORT EQUIPMENT:

0	Orbiter Bay Vertical Access Mechanism And Work Platform	1
0	Interior Access Assembly	2
0	Interior Access Assembly (Alternate)	2a
0	Mobile Power Generator	3
0	Portable Orbiter Hoisting Device	4
0	Orbiter Strongback	5
0	Piggyback Carrier Aircraft	6
0	RTG Handling Ring	7
0	RTG Handling Ring Sling	8
0	RTG Support Yoke	9
0	RTG Handling Dolly	10
0	RTG Handling Rod	11
0	Payload Changeout Room Cargo Handling Fixtures	12
0	Modified Payload Manipulator	13

BROWN ENGINEERING
A TELEDYNE COMPANY

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
ORBITER BAY VERTICAL ACCESS MECHANISM AND WORK PLATFORM	C-1

FUNCTION:

The function of this structure is to provide maintenance personnel and technicians an access to the cargo and cargo bay when the Orbiter is in the vertical position at the PAD.

DESCRIP[illegible]ON:

This [illegible]it shall be an integral part of the PCR or otherwise be substantially moun[illegible]d to it. It shall be capable of vertical and horizontal movement and later[illegible] motion by means of a telescoping boom. The unit shall be provided with [illegible]ucket or basket attached to the boom to hold personnel. The controls shal[illegible]e operable from the bucket by the maintenance personnel.

EXPERIMENT ☐ FACILITY ☒ STE ☐ GSE ☐

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:

INTERIOR ACCESS ASSEMBLY

ITEM NUMBER:

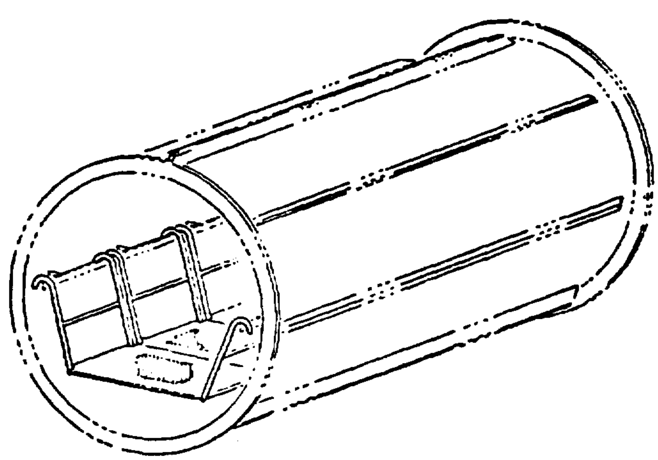
C-2

FUNCTION:

The function of this item is to provide supported capability to enter or leave the Spacelab through the Spacelab Crew Transfer Tunnel or segments of the tunnel while in the horizontal configuration under 1 g conditions.

DESCRIPTION:

The interior access assembly will consist of folding metal platforms which will attach to the IVA handrails in the tunnel to provide a crawl platform for ingress/egress. The platform segments will be designed for ease of installation with the tunnel either installed or not installed in the Orbiter. Their length will be compatible with all possible tunnel configurations.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

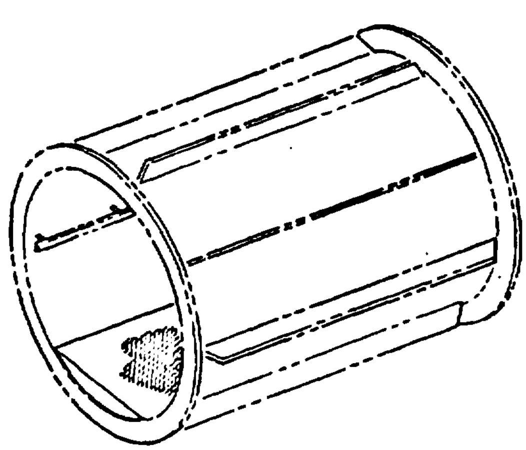
TITLE:	ITEM NUMBER:
INTERIOR ACCESS ASSEMBLY (ALTERNATE)	C-2a

FUNCTION:

The function of this item is to provide supported capability to enter or leave the Spacelab through the Spacelab Crew Transfer Tunnel or segments of the tunnel while in the horizontal configuration under 1 g conditions.

DESCRIPTION:

The Interior Access Assembly will be designed to provide a flat surface inside the Tunnel for personnel access into the tunnel. The assembly will be contoured to the curvature of the tunnel to distribute the personnel weight and prevent damage to the interior surface. The access assembly will be designed in length to accommodate either a tunnel segment or an assembled tunnel.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
MOBILE POWER GENERATOR	C-3

FUNCTION:

The function of this unit is to provide power to certain critical instrumentation for status display.

DESCRIPTION:

This power generator system shall have compatible connectors to mate vith Orbiter connectors. The unit must have the capability of providing pow r to certain instrumentations for monitoring of critical parameters.

Access to boat tail of Orbiter for hookup could be provided by ladders via fire truck.

EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☐

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
PORTABLE ORBITER HOISTING DEVICE	C-4

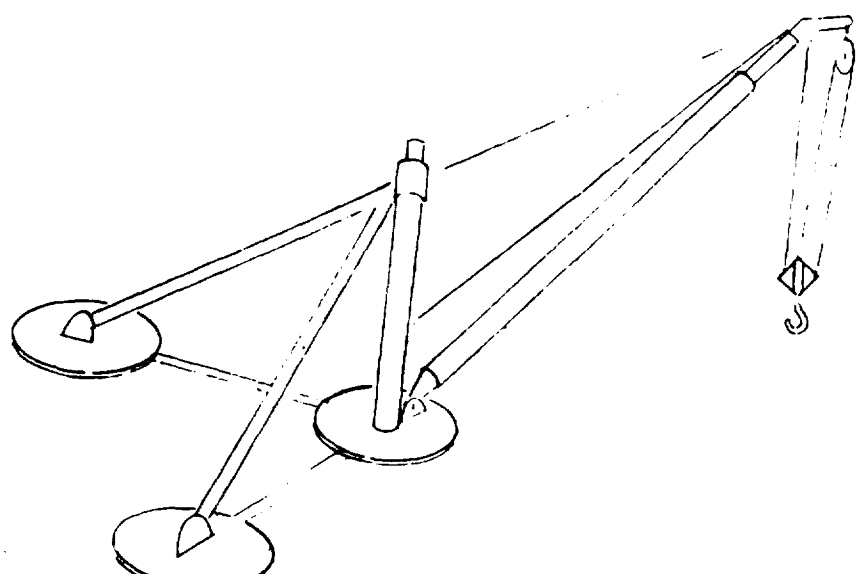
FUNCTION:

The function of this unit is to lift the Orbiter from the landing strip, translate, and position it onto a carrier aircrafts piggyback holding structure.

DESCRIPTI N:

This e .ipment shall have hoisting capability greater than 200,000 lb and be capabl of sufficient lat ral movement to achieve the above described function. It shall lso be designed for rapid assembly and disassembly. When disassembled, it shall e packaged for stowage and shipment in the Orbiter's carrier aircraft's cargo c npartment.

The sketch illustrates a guy derrick as one possible arrangement of such a mobile structure.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

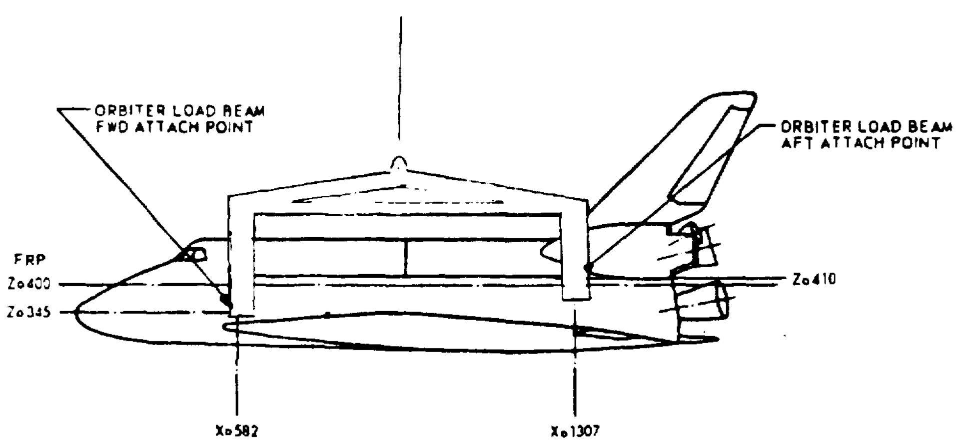
TITLE:	ITEM NUMBER:
ORBITER STRONGBACK	C-5

FUNCTION:

The function of this structure is to support the Orbiter at the forward and aft load beam attach points so that the Orbiter can be hoisted while in the horizontal mode.

DESCRIPTION:

This unit shall be attached at four load points. It may be a rigid structur · or could be a sling arrangement.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

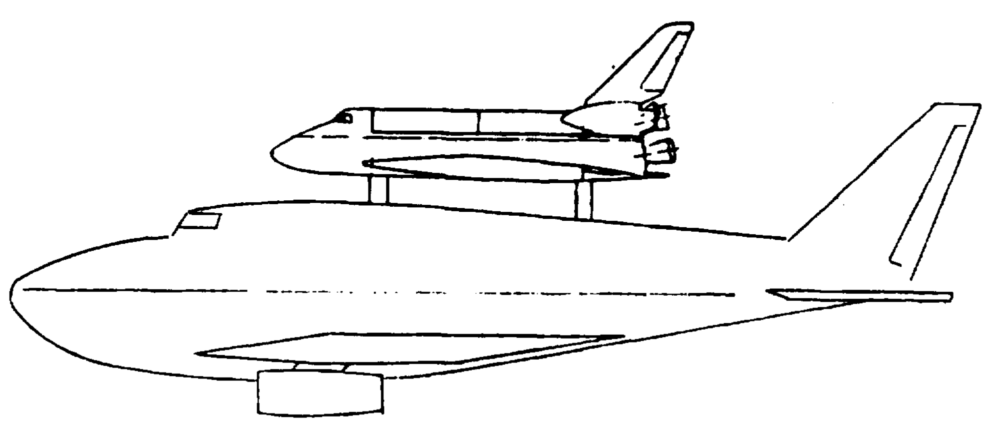
TITLE:	ITEM NUMBER:
PIGGYBACK CARRIER AIRCRAFT	C-6

FUNCTION:

The function of this aircraft is to ferry the Orbiter from an alternate site to KSC.

DESCRIP ON:

This arrier aircraft shall be capable of carrying a gross weight in excess of 200,000 lb. .e aircraft shou d be a Boeing 747 or similar aircraft capable of being conve te d. Modificat ons must consist of truss-work to distribute the weight of the two p g back load po nts throughout the aircraft's basic load bearing structure. Both re and aft locations where the Orbiter's attachments will be mounted shall be co npatible with the Orbiter's ET attachment points.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☐

SUPPORT EQUIPMENT IDENTIFICATION

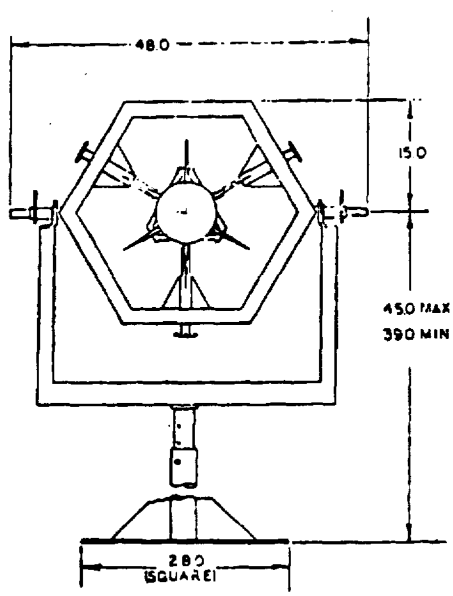
TITLE:	ITEM NUMBER:
RTG HANDLING RING	C-7

FUNCTION:

The RTG handling ring procides a means of handling a pair of connected RTG's from the center of the pair. It is used during most handling operations.

DESCRIPTION:

The RTG handling ring shall be hexagonally shaped and composed of rectangular aluminum tubing. Three quick disconnect fittings on the ring frame shall match holes on the delta frame structure. Trunnion shafts on the ring shall interface with bearing brackets on the RTG Support Yoke. Attachment brackets shall be provided at the ends of the trunnion shafts for connection of a RTG Handling Ring Sling.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

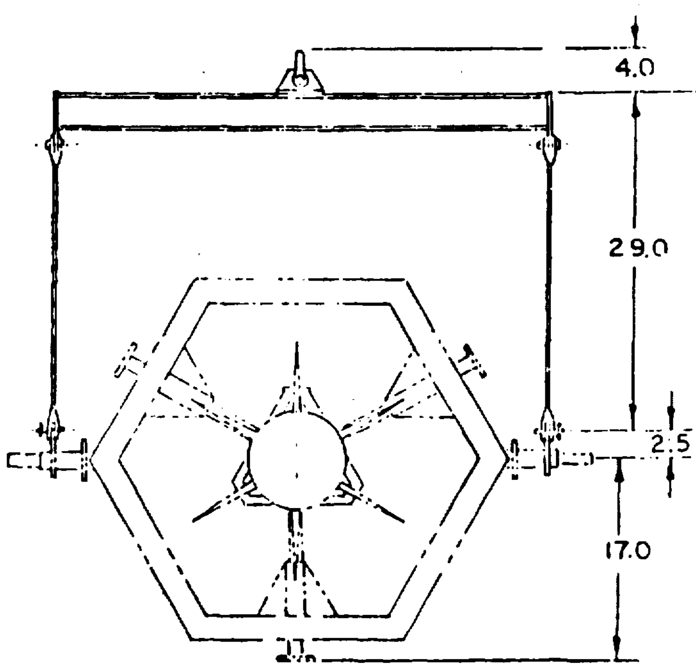
TITLE:	ITEM NUMBER:
RTG HANDLING RING SLING	C-8

FUNCTION:

The function of the RTG handling ring sling when used in conjunction with overhead cranes and a handling ring is to handle a pair of connected RTG's.

DESCRIPTION:

The sling shall consist of a straight beam with a wire rope cable suspended from each end. Fork ends on the cables shall be compatible with attachment brackets on the handling ring. These brackets shall allow the RTG's to be rotated from a vertical to horizontal atlitude while suspended from the sling.



EXPERIMENT [ ] FACILITY [ ] STE [ ] GSE [X]

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
RTG SUPPORT YOKE	C-9

FUNCTION:

The function of the RTG support yoke (when used in conjunction with a handling ring) is to support a pair of connected RTG's.

DESCRIPTION:

RTG support yoke is a "V" shaped structure mounted on a t ıbular post that supported in a socket that is attached to a base plate. The :TG's are capa›le of being rotated in the yoke and locked in position.

See Support Equipment Identification item number C-7 for sketch of RTG Support Yoke.

EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

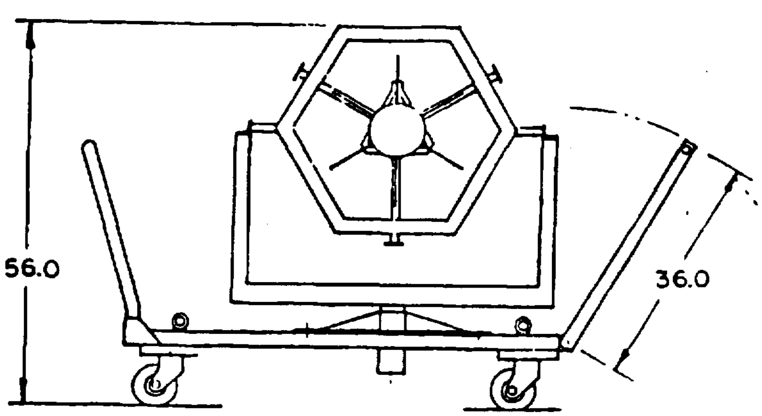
TITLE:	ITEM NUMBER:
RTG HANDLING DOLLY	C-10

FUNCTION:

The function of the RTG handling dolly is to provide mobile support for a pair of RTG's while they are mounted in an RTG Support Yoke.

DESCRII ION:

This :em shall consi ;t of a steel platform approximately 30 by 36 in., mounted on rı ber tread castı rs 8 to 10 in. in diameter. It shall be manually contr lled by a remo able handle. A socket shall be provided on the platform to ma :h the vertical ɔost on the yoke. With the vertical post removed, the RTG' mounted on the delta frame-bipod assembly are bolted to the dolly bed for t nsportation.



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

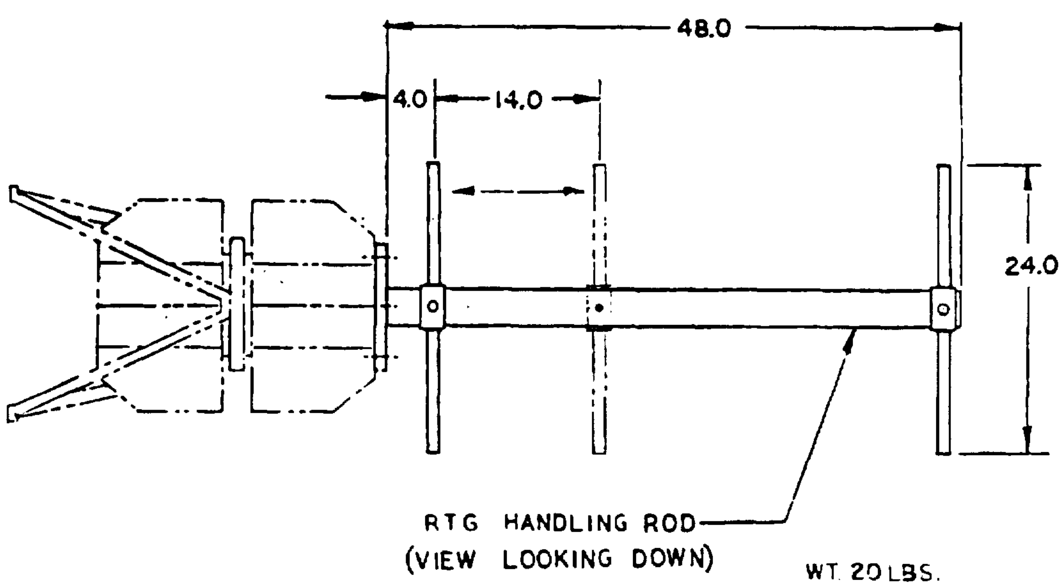
SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
RTG HANDLING ROD	C-11

FUNCTION:

RTG Handling Rod is used to hold a pair of RTG's in a horizontal position while the pair is passed through the fairings and mated to the PJP spacecraft.

DESCRIPTION:



EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:

PCR CARGO HANDLING FIXTURES*

ITEM NUMBER:

C-12

FUNCTION:

The function of the handling fixture is to hold a cargo in the vertical position in the PCR.

DESCRIP: O :

Two rgo handling fix ures should be built into or otherwise made an integral part tne PCR. One of these units shall hold a secondary cargo to be exchanged for t primary cargo in the event the latter is to be removed. The other unit shal old the first cargo during the exchange transaction required to remove it fron ne Orbiter Bay and to install the second. These fixtures shall hold the carg by installing it to the cargo flight attachment points in the same mode as in the Orbiter Bay.

* Required only if vertical changeout at the PAD is to be accomplished by having the PCR accommodate two cargoes simultaneously.

EXPERIMENT [ ] FACILITY [X] STE [ ] GSE [ ]

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
MODIFIED PAYLOAD MANIPULATOR*	C-13

FUNCTION:

To hold, handle, move, and position a cargo in the PCR.

DESCRIPTION:

The modified payload manipulator, in addition to the movement in and out of the Orbiter bay, shall also have the capability of a side to side movement. The manipulator shall be able to attach to and pick up a cargo in the Orbiter Bay, back out into the PCR, turn 90^{o}, and move the cargo into a PCR cargo handling fixture. This process shall also be reversible.

*Required only if the vertical changeout at the PAD is to be accomplished by having the PCR accommodate two cargoes simultaneously.

EXPERIMENT ☐ FACILITY ☒ STE ☐ GSE ☐

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:

MOBILE H_2O COOLING UNIT

ITEM NUMBER:

C-14

FUNCTION:

The function of the Mobile H_2O Cooling Unit is to provide cooling water to the RTG's Cooling System.

DESCRI ON:

This ıobile cooling u it shall consist of a tank trailer assembly with compatible hose onnections to th e Orbiter/cargo interface with pump and flow regulation capa lities. The uni could be towed by an attachment to the Orbiter tow vehicle or p ered by a separate tow truck that would be driven along with the Orbiter.

EXPERIMENT ☐ FACILITY ☒ STE ☐ GSE ☐

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
HOT GN_2 SERVICER	C-15

FUNCTION:

The function of this unit is to provide heated GN_2 to the IUS LF_2 tank to accelerate the boil off of gaseous fluorine.

DESCRIPTION:

The unit shall include a mobile tank with heating capability that can be connected to the portable GN_2 supply and transfer kit. It shall consist of appropriate transfer lines for interfacing with the GN_2 supply and the Orbiter/cargo. It shall include temperature indicators and controls and flow indicators.

EXPERIMENT [ ] FACILITY [ ] STE [ ] GSE [X]

SUPPORT EQUIPMENT IDENTIFICATION

TITLE:	ITEM NUMBER:
PORTABLE LN_2 SUPPLY AND TRANSFER KIT	C-16

FUNCTION:

The function of this kit is to provide means of transporting, connecting to Orbiter, and transferring LN_2 to pressurize and/or purge tanks and lines.

DESCRIPTION:

The kit shall include a mobile tank, transfer lines, control valves, sensors, interface connections, flow indicators, etc.

EXPERIMENT ☐ FACILITY ☐ STE ☐ GSE ☒

3.6 FACILITY PROTECTION AND PERSONNEL SAFETY

In most cases, contingency processing plans require inherently more hazardous operational sequences than do the normal processing plans. The contingency plan is used in extreme emergency conditions (an accident or schedule failure) when the normal processing plan is, of necessity, temporarily abandoned. Therefore, a contingency plan requires emergency action under stress conditions that are not conducive to good safety practices but where such practices are needed the most. Every effort has been made to provide the safest plan for each contingency situation that is also the least time consuming. Safing requirements for each contingency flow have been identified in previous sections of this report.

In the description of the special support equipment, human factors, personnel safety, and facility protection were considered and called out as required. Even though contingency plans often require more risky operations than normal processing plans, the same precautions and prudent actions by personnel should be exercised, such as the use of personal protective gear and clothing and the following of safe operational practices.

Volume 5 provides six sections devoted to applicable operational safety criteria:

- RTG Operational Safety Criteria . . . . Section 3.2.2
- Electrical Operational Safety Criteria . . . . Section 3.2.4
- Pyrotechnic and Solid Propellant Motors Operational Safety Criteria . . . Section 3.2.6
- Liquid/Gas Propulsion and Auxiliary Propulsion Equipment Operational Safety Criteria . . . . Section 3.2.8
- Toxic Fluids/Gases Operational Safety Criteria . . . . Section 3.2.9
- General Safety Criteria Applicable to Payloads . . . . Section 3.3

The safety criteria contained in Volume 5 is the result of the synthesis of applicable safety requirements, guidelines, and criteria extracted from such documents as Kennedy Space Center Safety Practices Handbook, Shuttle Payload Ground Operations Safety Handbook, etc., and tempered with the findings of this study. These criteria should be given consideration in any safety tradeoffs involving hazardous contingency plan operations.